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VOL. X. NEW YORK, FEBRUARY, 1906. No. 12.

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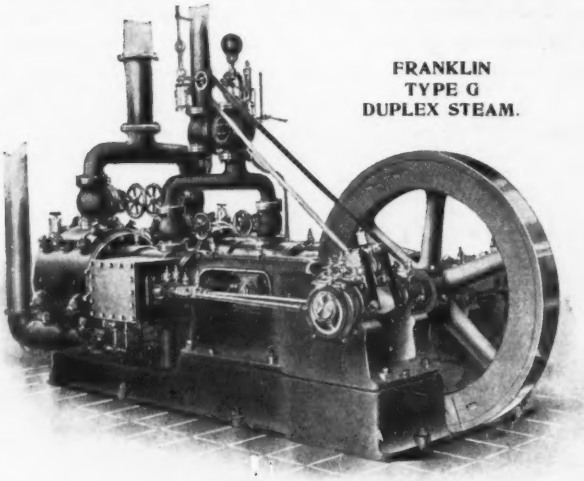

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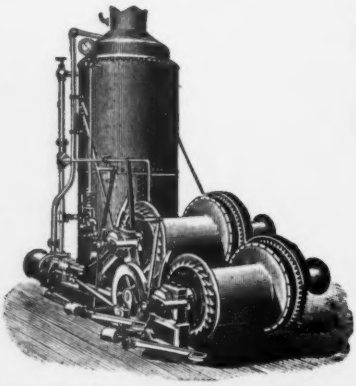

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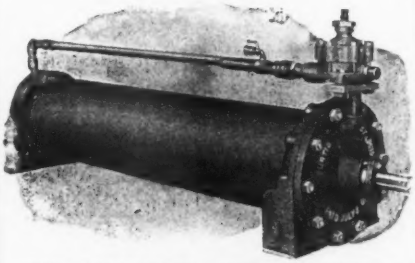

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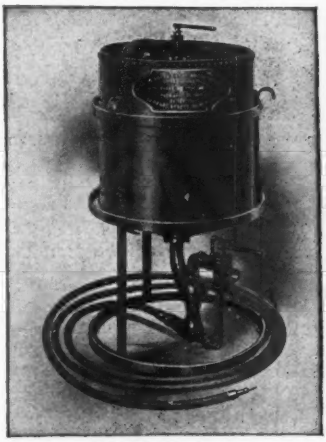

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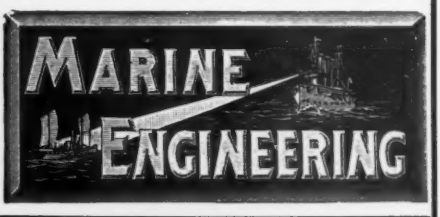

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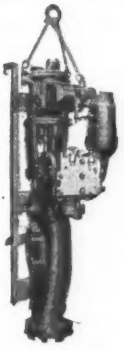

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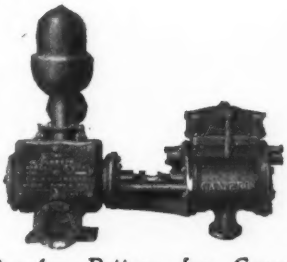

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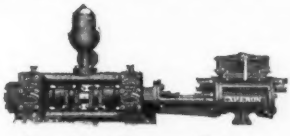

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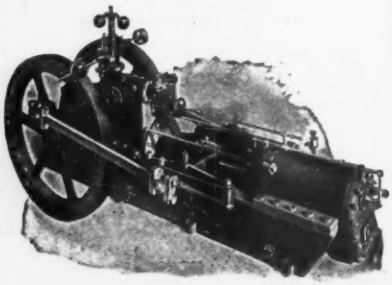

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VOL. X. FEBRUARY, 1906. NO. 12

Cost of the Air Lift.

Those who have given any study to the subject of raising water by compressed air must admit the practicability of the air-lift pump as installed by several of the companies now in that field. Once the practicability admitted, the question of cost compared with other systems of pumping is immediately raised. It is natural that, at first, the air lift should have been somewhat lacking in the efficiency that can be secured, now that the experimental stage is past. In discussing the theory of the air lift in a previous editorial, we called particular attention to the need of proper proportions for the well and air piping. There is no hard and fast rule on this subject and it required experience with varying conditions to best adjust these details to secure the most economical results. Improvements in well piping and a better understanding of conditions have combined to reduce both the pressure and the volume of air needed. With this reduction in compressed air required has come a marked improvement in the efficiency of the air compressors which has lessened the cost of compressing the air. All these influences have combined to reduce the costs far below those secured at the first plants installed and to place the air lift in its particular field, as a formidable rival of the deep well pump.

One of the companies now installing the air lift reports an interesting case in Indiana where the air lift clearly demonstrated its superiority to the deep well pump. The compressor was a second-hand "straight-line" machine of 18-inch stroke. Two belt-driven pumps, with cranks and pitman, giving a double-acting effect with a definite length of stroke, were installed. They were driven by an ordinary portable engine and boiler. The test was conducted by a well-known consulting engineer employed by the city to make tests to determine which system should be installed. The tests were very thoroughly made and definitely showed that while the deep well pump raised sixty gallons of water per pound of coal burned under the boiler, the air lift, under the same conditions, raised 300 gallons per pound of coal burned. While it is admitted that a much higher efficiency could have been secured for the pump by the use of an economical engine, it must be remembered that the use of a Corliss compound compressor would have given far better results in the case of the air lift.

Readers of "COMPRESSED AIR" will have noted other instances where the same general results were repeated. There can be no question to-day as to the success and economy of the air lift in the field of deep well pumping. There is, however, still an opportunity for a further development of this method of pumping which will make compressed air an even more important factor in this field than it is to-day.

General Herman Haupt.

Among the men who have been prominently identified in the progress and development of compressed air was General Herman Haupt, an announcement of whose death was made in the January issue of this publication. A career so important in its influence on this subject deserves more than a passing notice. General Haupt was one of the earliest advocates and firmest believers in compressed air. He has also been closely identified with the principal railroad enterprises in this country during the last fifty years and has filled many positions of trust and responsibility.

General Haupt was born in Philadelphia, March 26, 1817. His father died when he was but twelve years of age and left a family of seven children. There were no free schools in those days, so that young Herman earned his tuition by mending the quill pens and caring for the fire in winter. At the age of thirteen he received from President Andrew Jackson an appointment to the United States Military Academy which he entered the next year, and graduated in 1835. He was one of the youngest to enter the army and was the senior alumnus of the Academy at the time of his death. In 1838, he married Ann Cecilia Keller, the daughter of a Lutheran clergyman, at Gettysburg, Pa. Shortly after graduation he resigned from the army to accept the position of assistant engineer in the State service and located the line from Gettysburg to the Potomac across the South Mountain, which is now a part of the Western Maryland Railroad. It was during this time that he met his wife. He afterward established a seminary for boys and subsequently for girls at Gettysburg, which he continued until selected professor of mathematics in the Pennsylvania State College.

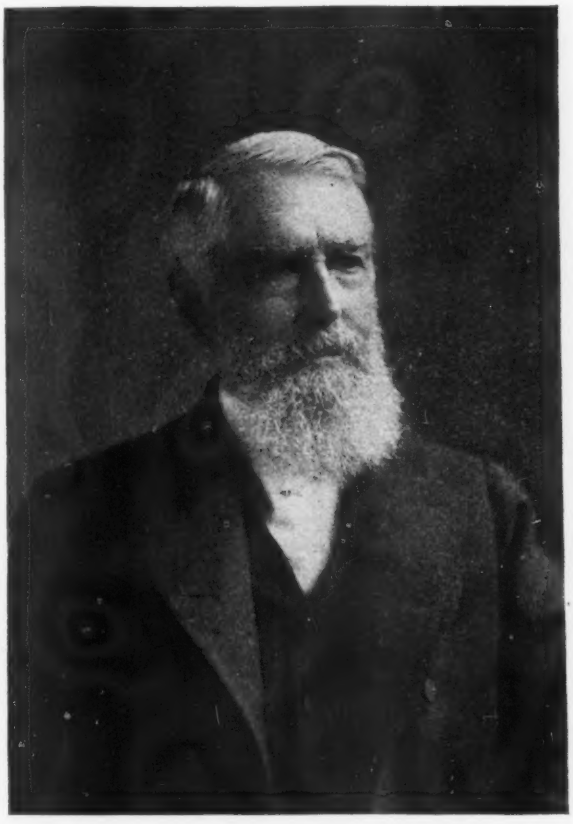
In 1840, while connected with the York and Wrightsville Railroad, he began the investigation of the strength of the old lattice trusses leading up to his first essay entitled, "Hints on Bridge Construction." This provoked much discussion and led to the more elaborate work published by the Appletons in 1851, which soon became the standard work on the science of "Bridge Construction," and gave to its author a world-wide reputation. In 1848 he was made principal assistant to J. Edgar Thompson on the Pennsylvania Railroad, afterward occupying many positions of importance, including those of general superintendent and chief engineer. Under his active supervision as chief engineer the entire road was opened to Pittsburg. He was then solicited to act as consulting engineer for the Hoosac Tunnel in 1885. He soon discovered that to make it a success it would be necessary to surrender his important interests in the Pennsylvania Railroad and give his undivided attention to the great problem of connecting the seaboard of the eastern States with the granaries of the west by penetrating the mountain by a five-mile tunnel. This required the complete reorganization and financing of a project as yet unprecedented in magnitude and which was violently opposed by rival interests.

This work was successfully inaugurated and was progressing satisfactorily when the Civil War and a change of administration called for the services of a man of large experience and great integrity to maintain the communications with the armies in the field. He was appointed by President Lincoln chief of the Bureau of Military Railroads with unlimited power and organized construction corps and systems for the rapid destruction or construction of railroads and bridges, as necessity demanded. His achievements excited the interest of the European powers because of the incredibly short time required to restore interrupted communications, and this system made the Sherman coup a successful possibility. He foresaw and correctly interpreted the strategic movement of General Lee after Meade had relieved Hooker as commander of the army of the Potomac, and by early information and rapid movements succeeded in having the position at Gettysburg, with which he was so familiar, held and made impregnable. Had his urgent entreaties been heeded the defeated army could not have escaped to Virginia and the war would have been ended. Fearlessly, by day or night, without consideration of personal comfort or necessities, did he apply his ceaseless vigilance to the perfection of his bureau and its personnel and the opening up of communications with the front, so that he was early offered a commission as brigadier-general "for faithful and meritorious services."

The tunnel exigencies required more rapid work than was possible by hand labor and led to the invention and success-

ful introduction of his portable percussion drills, afterward so successfully used in the great European tunnels through the Alps under the name of the McKean rock drill.

Another of Haupt's great achievements was the securing of a continuous right of way for a pipe line from the oil regions to the seaboard, prior to the existence of any general laws and the subsequent building of a line which reduced the cost of transportation on this important commodity from 40 to 4 cents a barrel, to the great relief of the railroads and the public. This was accomplished at a time when the producers could secure no transportation, unless members of the "System," and all the means and energies of one of the most potent organizations known in modern times was arrayed against the movement. Since its success, general pipe line laws have been passed and the system is now in extensive operation.



GENERAL HERMAN HAUPT.

In 1881, he was appointed the general manager of the Northern Pacific Railroad, which position he held until 1884, after the completion and opening of the line in the fall of 1883. He secured the great terminals, so necessary for the rapid

handling and interchange of freight. His foresight was severely criticised when he urged the purchase of the Powelton Estate on the west bank of the Schuylkill for the Pennsylvania Railroad, at a time when it was thought to be wholly unnecessary, but which to-day constitutes a small part of the present yards of that company.

To facilitate the movements of freight at the western end of the State of Pennsylvania, he also designed a system of improvements in the Ohio River for the creation of a six-foot stage at all seasons, which the river interests prepared to construct at a cost of $1,000,000, between Pittsburg and Wheeling, but the control of the works of this class by the General Government prevented the project from being carried out, at the time. In 1879, he was also president of the United States Hydrogen Co., organized to generate and apply that element to metallurgical and heating purposes. He was actively interested in the Holly system of steam heating and other application of the physical sciences to the arts.

In 1879, compressed air traction first attracted his attention. After a thorough investigation of the system he reported favorably of it, but failed to secure its adoption owing to the universal prejudice then existing against it. In 1892, he again resumed his efforts in compressed air traction and was elected president of the General Compressed Air Company, which operated a trial system of cars on 125th street and 128th and 129th streets, New York. General Haupt also brought out a book, "Haupt on Motors," in which the compressed air motor was strongly advocated.

His later years have been spent in the evolution of a pure, cheap and nutritious food, from the waste products of the dairy, so that humanity might have a "well balanced ration" at a reasonable cost, which could be readily used and transported to all parts of the globe and be of service in the army, navy, at sea or on land, in homes or hospitals, in short wherever pure milk is required, and which would keep for months without decomposition. It was in making a visit to the works of the National Nutrient Company in Jersey City, that he was overtaken by the heart failure that terminated so laudable a career. His later years have been devoted to social, humane and scientific study and writing and it was his purpose, if his life had been prolonged, to prepare a series of papers on these topics.

At the earnest solicitation of friends he has published in his "Memoirs" some of the principal events of the Civil War and the system used by his corps, in a subscription volume, profusely illustrated (1901).

As a man he was unostentatious, domestic, loving, tender-hearted, upright in all his dealings with his fellow-men in every capacity, having a keen sense of justice, righteousness and obligation to duty, regardless of appearances, faithful to every trust, and in every act inspired by his strong faith in the brotherhood of man and the fatherhood of God. His life has been an honor to his profession and a blessing to humanity, as an instance of a man whom the Lord delighted to honor.

The Electro-Pneumatic System of Train Control.*

To handle the enormous travel in and around the large cities, trains operated by electricity are being run, some by means of electric locomotives and others by multiple control. The use of electric locomotives is readily understood by its similarity to the steam locomotives. Several motors are here mounted on the trucks of a single car, which car furnishes all the power to draw the entire train. By multiple control is meant the operation of a train of cars all or at least a large number of which are motor cars. To do this it is at once apparent that some system must be provided whereby all the motors throughout the train will be controlled in perfect unison and by a single motorman. Distributing the tractive powers throughout the train greatly increases the flexibility of operation. A better schedule can be made, which means both greater accommodation to the traveling public and greater earnings to the road.

Every system of multiple control consists, in general, of motor-controlling devices located beneath each motor car as a part of the motor equipment and an operating circuit which connects the motor-controlling device on a car to the small controller on the platform at each end of the car. The train may be controlled from

* By P. C. McNulty, Jr., in the *Electric Club Journal.*

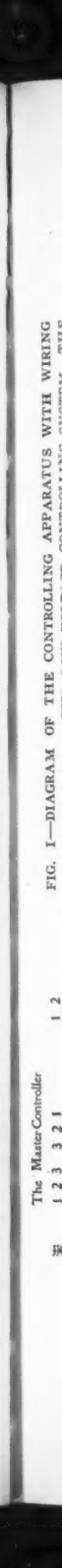


FIG. I—DIAGRAM OF THE CONTROLLING APPARATUS WITH WIRING

FIG. 1—DIAGRAM OF THE CONTROLLING APPARATUS WITH WIRING CONNECTIONS OF THE LOW VOLTAGE CONTROLLING SYSTEM. THE PICK-UP COILS, HOLD-UP COILS, INTERLOCKS AND UNIT SWITCHES ARE ALL REPRESENTED IN DETAIL.

any one of these controllers, but the one in the front cab of the first car in the train is, of course, the one generally used.

In the present system of running single cars the motor-controlling switches are operated by hand. In a train these switches must obviously be operated by some intermediate means. In the systems now in practical operation this is done either magnetically by solenoids or electro-pneumatically by air pressure controlled by magnetically operated valves.

It is the purpose of this article to describe the latter system, which has been developed by the Electric Company.

The characteristic feature of the Westinghouse electro-pneumatic system is the operation of the switches for controlling the motors by means of compressed air from the braking system. The air cylinders, when closing the switches, operate against powerful springs, so that when the air pressure is removed the springs will quickly open the switches. The cylinders are of generous size and the air pressure is 70 pounds per square inch, thus allowing the opening spring to be very strong, insuring a positive and reliable opening of the switch. The admission and release of the air is governed by electrically operated valves, the current for which is supplied at 14 volts by a storage battery. The entire operating circuit being at this low voltage gives the system several advantages, the more important of which are: Independence of the main circuit; low operating and maintenance cost, and safety to passengers and operators, since the currents at line voltage are in no case carried above the floor of the car.

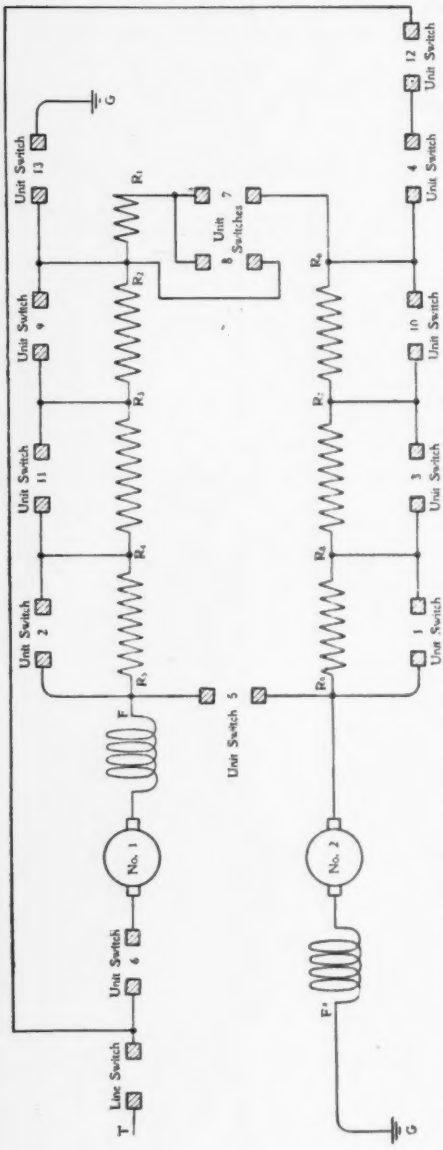


FIG. 2—WIRING DIAGRAM OF THE MOTOR CIRCUIT ON EACH CAR.

The Train Circuits.

There are two separate and distinct circuits on the train. These are:

(1) The low-voltage operating circuit.

(2) The high-voltage motor circuit.

The operating circuit is shown diagrammatically in Fig. 1 and is fed from storage batteries, one set on each car, at a pressure of 14 volts. This circuit is used to energize small electro-magnets, thus opening the valves that admit the compressed air to the main switches of the motor circuit. This is the only circuit that must be established from car to car, and is the only one that is brought into the body of the car.

The motor circuit, shown in Fig. 2, is an independent circuit on each car. It is at line voltage and is the same as the circuit on the ordinary trolley car, except that the series-parallel controlling device is beneath the floor of the car instead of in the motorman's cab.

The Master Controller.

A small controller, known as the master controller, is placed in the motorman's cab at each end of every motor car of the train. As previously stated, the controller in the front end of the first car is used to control the train, and all of the current for the operation of all the switches on the train passes through this on controller, but the current for the switches on each motor car is obtained from the battery thereon; thus, as is more fully explained later, the number of cars composing a train is unlimited.

The master controller handle has three positions for each direction of movement, the off position being in the centre. These are:

(1) The switching notch.
(2) The series running notch.
(3) The multiple running notch.

When the handle is turned without stop to the multiple running position, the car will start and build up to speed, with the full line voltage on the motors, at a uniform acceleration and without current interruption to the motors. If the hand is removed from the handle, it is at once brought to the off position, thus opening all of the switches.

The Limit Switch.

The rate at which resistance is cut out of the circuit is such that the accelerating circuit is practically uniform. This is accomplished by the use of a limit switch,

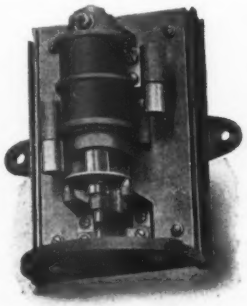


FIG. 4—THE LIMIT SWITCH.

shown in Fig. 4. This feature is very valuable, as it gives a smooth and economical acceleration and prevents abuse of the equipment by throwing on the power in excess of a predetermined rate.

This switch consists of a small solenoid in series with one of the motors. When the current rises above a predetermined limit, the armature of the solenoid is raised against gravity, thus lifting a disc off of two contacts in the operating circuit. The switches that are already in are held in, but no other can come in until the current falls off enough to let the disc down on the contacts again.

The Switch Group.

A controlling device, shown in Fig. 5, often spoken of as the turret controller—from the shape of its cover—is placed beneath the floor of the car. Its proper name is the switch group, and it consists of 13 independent or unit switches grouped radially around a large and powerful blow-out coil. There is a large air chamber just above the blow-out coil and in the centre of a casting which is bolted to the supporting frame. In this casting, directly above the inner end of each unit switch, is an air cylinder, and upon the outer edge of this cylinder casting are bolted eight iron-clad thoroughly protected magnet valves. When the magnet is energized its armature is lowered; this opens a valve and allows the air to pass from the air chamber to the cylinder, the air being supplied at a pressure of 70 pounds per square inch from an auxiliary air tank fed from the main braking tank. On its downward stroke the piston compresses a strong spring and closes its unit switch. When the circuit around the magnet is opened, the valve closes and opens the exhaust to the atmosphere. The piston is then forced up by the compressed spring under it, opening the switch. On the upper end of the piston rod is a small metal drum, and as the piston moves downward this drum makes or breaks the connection between the small fingers surrounding it, as shown in the cut. This closes or opens the circuit to the magnet of the next switch, thus closing or opening the switch. This is called the interlock, and it will be readily seen how resistance may be automatically thrown in or out of the motor circuit, since each unit switch shunts a block of resistance.

The switch arm carries contact fingers that are pivoted on the arm. A small spring under the inner end of these fingers compresses as the two contact tips engage, thus causing a wiping or rocking motion

of the fingers, which maintains a positive contact and upon which the wear is a minimum. The studs for the motor leads are supported by a plate that is bolted to the cylinder casting. These studs are insulated from the plate and with the connecting wires are inclosed in a tight insulating box, protecting them from dust and moisture, with sealed outlets for connection to the car wiring.

The supporting plate just referred to forms the upper part of the magnetic circuit for the blow-out coil. The lower part of this circuit is completed by a cast-iron spider with T-shaped pole tips.

lowing paragraphs illustrate the electric circuits that are established on one car or a train of cars equipped with the electropneumatic control, and by means of them it is possible to trace these circuits and determine the results produced by each movement of the master controller.

The diagram, shown in Fig. 2, gives all of the electrical connections in the line-voltage circuit between the trolley, the line switch, the motors, the switch group and the resistances on a single car, and shows how the unit switches vary the voltage on the motors by cutting out or connecting in resistance.

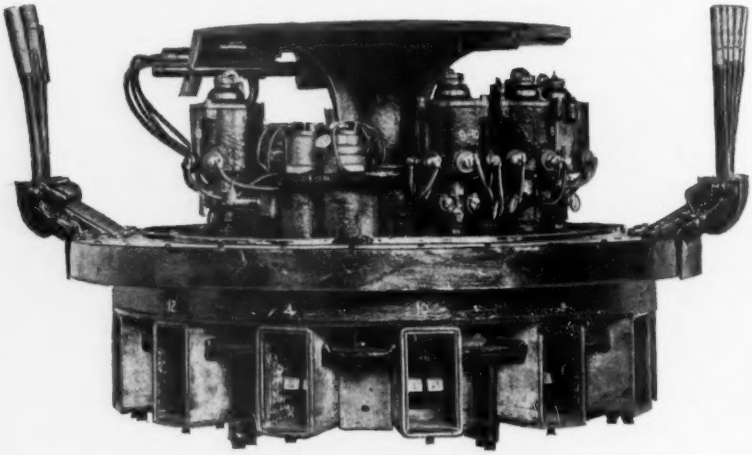


FIG. 5—THE SWITCH GROUP.

The switch group is inclosed in a turret-shaped sheet-iron cover, easily removable for inspection, which effectually protects the contacts from dust and moisture. The lower part of the cover is made in halves, each capable of rotating, one inside the other.

The normal position of all the switches is open, and any failure of the air supply or interruption of the operating circuit opens all the unit switches. The switches never stick or weld from heavy currents, because they are opened by the strong spring under the piston previously referred to.

The Wiring Diagrams.

The diagrams referred to below in connection with the explanations in the fol-

Fig. 1 shows all of the electrical connections between the various pieces of apparatus in the low-voltage circuit which operate the high-voltage switches of a single car.

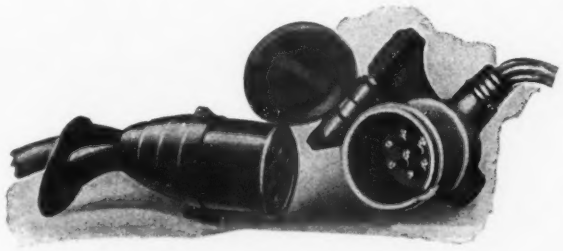
Fig. 7 shows the electrical connections that must be established to operate two or more cars from one master controller.

These diagrams will be taken up in the order just given to illustrate, first, the functions of the unit switches of the switch group on one car, then to show how these switches are made to perform their functions and, finally, to show the effect of operating more than one car from one master controller.

Each explanation is divided so that the circuits established on each notch of the master controller may be traced.

With the master controller in the off position a circuit is closed around the circuit-breaker reset coil as soon as a small knife switch, shown as the circuit-breaker reset in Fig. 1, is closed. The closing of this switch sends a current as follows: $B+$ through fingers No. 3 and No. 6 of the master controller, thence around the circuit-breaker reset coil to $B-$. This closes the circuit-breaker trip, shown as *CB* in the sketch. The master controller handle may now be turned one way or the other to test the air and the electrical connections of the operating circuit.

If the small knife switch, called the line-switch cut-out, be closed, a circuit may be established as soon as the master controller is turned to the first position; that will close all of the line switches on the train. The following paragraphs show the results of turning the master controller to other positions.



JUMPER CONNECTER.

THE MOTOR CIRCUIT.

The Switching Notch—When the master controller is turned to the first notch, the line switch and reverser are closed; then, switches Nos. 6 and 7 of the switch group are closed, as explained later, and the first flow of current through the motors is as follows: From trolley, Fig. 2, marked *T* through the line switch; No. 6 switch and No. 1 motor; thence, through resistances R_3 to R_1, to No. 7 switch, through this switch to R_6, then through resistances R_6 to R_9, thence through No. 2 motor into the ground return. Thus the motors are put in series with all of the resistance in the circuit.

The Series Running Notch—When the master controller is turned to the second notch, the No. 8 switch of the switch group closes; then the circuit described above will pass throught this switch, thus shunting R_1 to R_2 and raising the voltage on the motors. The closing of No. 8 switch causes switches 9 and 10 to close; this closes switches Nos. 11 and 3, and they, in turn, close switches Nos. 1 and 2. This action is fully described later. As may be seen from the diagram, each switch as it closes shunts a block of resistance so that when all of the switches named above are closed the motors are in full series and the flow of current is as follows: From trolley through the line switch, No. 6 switch and No. 1 motor, thence through switches Nos. 2, 11, 9, 8, 7, 10, 3 and 1 in the order given, then through No. 2 motor and into the ground return. The motors are now running in series with no resistance in the circuit and the change over to the parallel may be made.

The Multiple Running Notch—When the master controller is turned to the third position, No. 5 switch closes, thus causing switches Nos. 7, 8, 9—10, 11—3 and 2—1 to open simultaneously, as described later. This causes a flow of current from *T* through the line switch, No. 6 switch, No. 1 motor, No. 5 switch, No. 2 motor and into the ground return. As the No. 7 switch opens it causes switches Nos. 4, 12 and 13 to close. The No. 4 switch closing opens the No. 5 switch, and the change from series to parallel has been made without breaking the circuit. The first circuits in multiple are established as follows: From *T*, through the line switch, No. 6 switch, No. 1 motor to R_8, thence through R_8 to R_2, then through No. 13 switch and into the ground return. Also

from T through switches Nos. 12 and 4 to R_8, thence through R_8 to R_9, then through No. 2 motor and into the ground return. Switches Nos. 9—10, 11—3, 1 and 2 automatically close as on the previous notch, as soon as the limit switch will allow, as explained later. Each switch shunts its resistance until, when all the switches are in, the motors are running in full multiple and the current is flowing as follows: From T through the line switch, No. 6 switch and No. 1 motor, thence through switches Nos. 2, 11, 9, 13 and into the ground return. Also, from T through switches Nos. 12, 4, 10, 3, 1, then through No. 2 motor and into the ground return.

Thus it is seen that the motors on a single car are now in full multiple and controlled as one motor. Later it will be shown how the motors on every car of the train are controlled simultaneously as one motor.

The Operating Circuit.

The Switching Notch—When the master controller handle is turned to the first notch the line switch, line relay and reverser are closed. As soon as the interlock on the reverser closes, the switches Nos. 6 and 7 of the switch group are closed. This throws the two motors into series and brings all of the resistance into the circuit.

By reference to Fig. 1 it will be seen that the circuits which are established to close these switches are as follows:

From $B+$ of the battery to $B+$ in the master controller, then through $5S$ to the line switch cut-out, which has already been closed by hand, thence through 5 around the magnet on the line switch and back to B—through the circuit-breaker trip. This closes the line switch and the line relay and opens the interlock shown above the line switch.

At the same time the current flows from $B+$ to finger No. 1 or No. 2 on the master controller, according whether the handle is turned in the forward or reverse direction, then around the magnet No. 1 or No. 2 on the reverser, as the case may be, and then to $B-$. This closes the reverser, and as it closes its interlock closes, thus establishing the circuit marked R, from No. 1 or No. 2 magnet of the reverser to the magnet on No. 6 switch of the switch group.

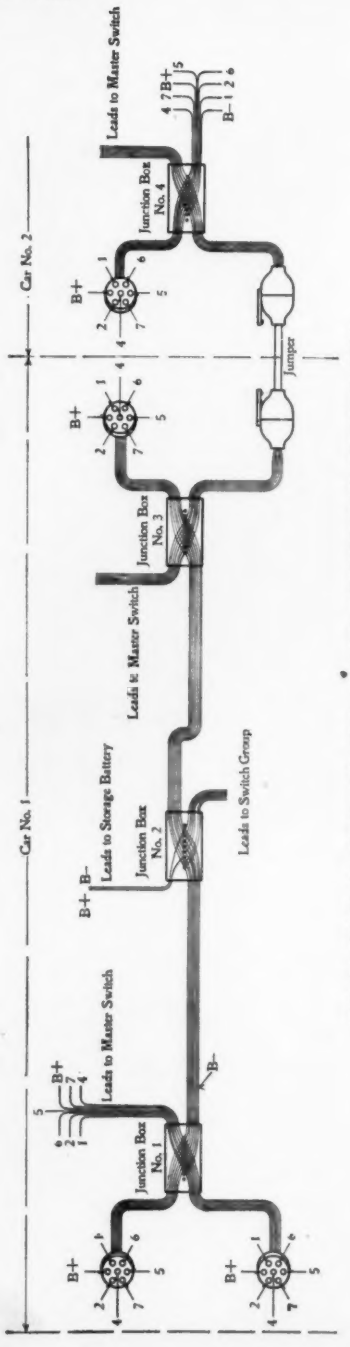


FIG. 7—DIAGRAM SHOWING THE JUMPER CONNECTIONS BETWEEN CARS.

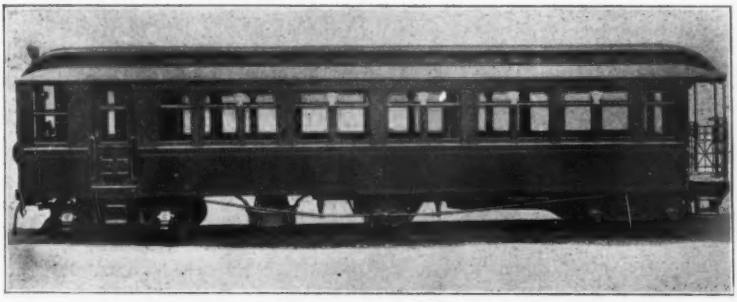
From this magnet the current returns to *B*—, shunting the No. 6 interlock, through the line relay and the circuit-breaker trip.

This closes the No. 6 unit switch, as described under paragraph, switch group, thereby closing its interlock and establishing a circuit through the magnet of the No. 7 switch as follows: *R* being energized and the interlock on No. 6 closed, as just described, the current flows from *R* through the magnet on No. 7 switch to No. 13 interlock, thence through interlocks Nos. 5, 4 and 6 to the line relay and through the circuit-breaker trip to *B*—.

This closes the No. 7 unit switch, thereby causing the current to flow through the motor circuit, as previously described.

From *B*+ through No. 4 to the limit switch, thence through *L* around magnet No. 9 and No. 10; then through interlocks 8-5-4-6, in the order given, and to *B*— through line relay and *CB*. This closes these switches which closes interlock No. 9. The closing of No. 9 interlock closes switches No. 11 and No. 3 in the same way, and No. 11 interlock closes switches No. 1 and No. 2.

The diagram shows two windings on all of the magnets except No. 6 and No. 7. These windings are known as the pick-up coils and the hold-up coils respectively, as marked in the sketch. It has already been seen that a circuit around the pick-up coil closes the switch, and reference to the sketch will show that as soon as the inter-



CAR EQUIPPED WITH ELECTRO-PNEUMATIC SYSTEM OF TRAIN CONTROL.

The Series Running Notch—If the handle is turned to the second notch, No. 4 finger in the master controller is joined to *B*+, as may be seen from the sketch. This causes the switches No. 8, No. 9—10, No. 11—3, No. 1—2 of the switch group to close automatically in the order given. When these switches have all closed the motors are running in series with all of the resistance out, as previously shown. From the diagram it will be seen that current may now flow from *B*+ to No. 4 finger, then shunting the limit switch to the magnet on No. 8 switch, around this magnet and through interlocks No. 5, No. 4 and No. 6 to the line relay and through the circuit-breaker trip to *B*—, as described before. This closes the No. 8 switch, and as its interlock closes a circuit is established around the magnet on switches No. 9 and No. 10, as follows: lock or any switch is closed the hold-up coil is brought into the circuit that picks up switches Nos. 6 and 7. Then if the limit switch breaks the pick-up circuit, the switch that has closed is held in by the hold-up coil, but the next switch cannot pick up until the limit switch has closed again.

The Multiple Running Notch—When the handle of the master controller is on the third position the No. 5 switch closes, and in so doing opens switches Nos. 7, 8, 9 and 10, 11—3, 1—2, as stated above. As the No. 7 switch opens its interlock closes the circuit around the magnet on switches Nos. 4, 12 and 13. These circuits are established as follows: From *B*+ to No. 7 finger of the master controller, thence to the motor cut-out switch. From this switch through *M* to the magnet on No. 5 switch, thence through the interlocks 1-13-

5-4 and 6; then through the line relay and *CB* to *B*—. This closes No. 5 switch.

The interlock on this switch is a special four-point interlock, and is so made that the circuit around switches Nos. 7, 8, 9—10, 11—3, 1—2 is broken as the switch closes, and the circuit around the magnets on switches Nos. 4, 12 and 13 is established as soon as the No. 7 switch is opened. The interlock on No. 7 switch is a reverse order; that is, when the switch is open the interlock is closed, and vice versa. Therefore, when No. 5 switch opens No. 7 switch, as just explained, the interlock on No. 7 switch closes the following circuit around the magnet on switches Nos. 4, 12 and 13: From B+ to 4, thence through the limit switch through *L* to magnets Nos. 4, 12 and 13; thence through No. 7 and No. 12 interlocks to the low contact of No. 5 interlock; then to the high contact of No. 4 interlock; thence through No. 6 switch, line relay and circuit-breaker to *B*—. This closes switches Nos. 4, 12 and 13. As the No. 4 interlock closes it opens the circuit around No. 5 switch, thus opening this switch as soon as No. 4 switch is closed. The opening of this switch, with the closing of No. 4 switch, changes the motors from series running to parallel running, as mentioned above.

If the current has not risen above the limit of the limit switch a circuit is established around the magnet on the Nos. 9 and 10 switches as soon as the No. 4 interlock is closed. If the limit switch is opened by the current rising above its limit this circuit is not completed until the current has fallen enough to allow this switch to close, and then the circuit is as follows: *B*+ to 4 through the limit switch; thence through *L* to No. 9 and No. 10 magnet; thence shunting No. 9 interlock to the low contact of No. 4 interlock; thence through No. 6 interlock, line relay and *CB* to *B*—. This closes switches Nos. 9 and 10, and they in turn close Nos. 11 and 3, which closes Nos. 1 and 2, as described on the series running notch.

The Train Connections.

The diagram shown in Fig. 7 shows how the wires of the operating circuit are connected from the master controller to the apparatus on a car and to the train cable by means of the junction boxes. The letters on the junction box terminals correspond with the letters on the circuits that were described in the operating circuit.

This train cable consists of seven of these 14-volt wires, as shown in the sketch, and runs throughout the length of the train. The connection from car to car is made by means of a jumper.

Thus it is seen that the apparatus on each car is really paralleled on to this train cable, and it illustrates, as was mentioned before, how the total current for operating all of the switches of the train must pass through the master controller that controls the train, but the current for the apparatus on each car is furnished by the battery thereon. This explains how all the motors on the train are made to act simultaneously and uniformly, and shows that, by distributing the power throughout the train and using multiple control the train may be started with smoothness and rapidity.

The Use of the Elmo Harris Return-Air System for Pumping Coal Mines.

In a large proportion of the coal mines, especially in the bituminous district, the compressor equipment is usually of a type which is not of high efficiency, as regards steam consumption. As a rule, the plant consists of boilers capable of carrying approximately 100 pounds of steam, and the compressors are of the straight line type. In some instances the air ends are compounded, but the gain in efficiency due to this is very small compared with what might be realized if a machine of the Corliss type were installed.

Usually straight line compressors are provided with Meyer cut-off valves; but engineers as a rule do not pay sufficient attention to this fact, and in many cases the cut-off is adjusted to a point so late in the stroke that the gain in expansion is nearly all lost. This increases the steam consumption and materially adds to the fuel expense.

It may be argued that coal at the mines costs very little and if the plant is charged with the coal at mining costs the loss due to the low economy is not so apparent. On the other hand, however, some operators are beginning to realize that the value of the coal should be considered as the market price and not the mining cost. On this basis the saving in fuel effected by the use of

efficient machinery becomes of no little importance, and the advantages of the Corliss compressor become very apparent. Other savings also apply which are not usually considered, namely, the cost of firing, the additional horse power of boilers made necessary by the high steam consumption, and further a shortage of boiler horse-power is apt to occur, which might otherwise be avoided.

The foregoing are well known arguments in favor of high grade machinery at coal mines, and are arguments which mine operators are more and more coming to appreciate, but the question invariably is raised that, although the saving effected by compressors of the better class might be considerable, their adoption would mean the discarding of the present equipment, which would involve a sacrifice of invested capital too great to be for a moment considered.

This is short-sighted policy, and furthermore it is a mistake to think that the present compressors must be discarded. By means of the Elmo Harris Return-Air System of pumping by compressed air the old compressors may be employed for pumping the mine and effect an economy over the present method of handling the water, with direct-acting steam pumps, so great in itself, as to warrant its adoption, even if the old compressors did not enter into the question.

Ordinarily the mines discharge from the various sags in the contour of the entries and rooms to the main sump, at which sump is installed one or more steam pumps lifting the water to the top of the shaft. These pumps are almost invariably of the direct acting type, single or duplex.

Steam pumps of this character are notoriously inefficient, and the steam consumption is very large, even when new and under the most favorable conditions, and in the event of the pump not being properly cared for and the pipe lines not properly covered, after a short time the steam consumption becomes an amount far greater than is ordinarily realized.

A brief description of the Elmo Harris Return-Air System would be as follows:

In the sump, preferably submerged, are two tanks. Leading from each tank to the compressor is an air pipe and leading from the tanks, with a suitable check valve arrangement, is a single water discharge pipe. The air pipes connect in the engine room in a switch and through this switch are connected to the compressor, one tank being connected to the inlet and the other to the discharge side of the compressor. The operation of the system consists in transferring the charge of air from one tank to the other. The air is withdrawn from one tank and compressed into the other, allowing the first tank to fill with water and displacing the water from the second, forcing it out through the discharge pipe. When this tank is emptied of water the switch is automatically shifted, so as to connect the tank which has been filling with water to the discharge side of the compressor and connect the tank, from which the water has just been expelled and which is full of air under pressure, with the inlet side of the compressor. In transferring this air, then, to the other tank the energy stored in it is recovered. The air entering the compressor under pressure exerts its force upon the receding piston and supplies a part of the power required for compressing the air on the opposite side. The additional power to be furnished by the engine is therefore only that due to the difference between the pressure of the air entering the compressor and that being discharged from it. In this way the expansive force of the air is realized in assisting the compressor to do its work, and consequently the water is pumped at a high rate of efficiency.

In order not to operate at an excessive air pressure, which would necessitate extra heavy piping and fittings, an approximate practical limit of single stage pumping may be set at 300 feet head, and in cases where the lift exceeds this it is better to place one tank at the bottom of the shaft and the second one in a sump at half the depth. This produces a system delivering half the water in two lifts with an air pressure equal to half of the total head, and with practically no increase in the equipment or cost of operation.

From the foregoing description it will be seen that the air operates in a closed system and that the intake pressure is constantly varying. On this account single-stage air compressors are always used. This applies to the air end only, and highly refined steam ends may be used with a corresponding increase in the

efficiency. In the example that follows, straight-line compressors are considered on account of their prevalence in mining districts, and because we have suggested their use for this purpose in the event of their being replaced by Corliss compressors for the usual mining purposes.

To explain the action in a mine, a typical case may be considered, for example, 500 gallons of water per min. lifted through a shaft 200 feet. Let us assume the starting point of the calculation to be the actual horse-power developed in the water lifted. In this case, we have

$$\frac{500 \text{ gals.} \times 8.3 \text{ lbs. per gal.} \times 200 \text{ ft. lift}}{33{,}000} = 25 \text{ horse power}$$

Assuming that the efficiency back to the steam cylinder is the same for the Elmo Harris Return-Air System and a steam pump, and still further assuming that this efficiency is 60 per cent., we have an indicated horse-power in the steam cylinders of 41.75 to produce the 25 horse-power of water lifted.

In making this assumption we are favoring the steam pump, inasmuch as this efficiency will decrease as the pump wears, while in the case of the Elmo Harris Return-Air System it will remain constant, but in any event under our assumption we have the indicated horse-power in the steam cylinder 41.75 stated. The steam consumption of a straight-line compressor under the varying load, that occurs in this system of pumping, we will assume to be 40 pounds of water per horse-power per hour. For the steam pump the consumption will be not less than 150 pounds per horse-power per hour.

From these figures it is seen that the steam consumption of the steam pump is 6,262 pounds per hour, and with the Elmo Harris Return-Air System is 1,670 pounds per hour, or a saving of 4,592 pounds per hour.

Assuming the evaporation of the boilers to be 7 to 1 a saving is produced of 656 pounds of coal per hour, or in a year, assuming 24 hours a day, pumping every day, an ultimate saving of 2,566 long tons of coal. When the price of coal charged against any plant is known, the actual saving in dollars may be obtained. This, however, is but one argument in favor of the proposition.

The second one would be that the pumps may be operated with between one-third and one-fourth of the boiler horse-power with a corresponding reduction in the cost of firing to be charged against pumping; also a reduction in the overloading of the boilers where there is a shortage of boiler horse-power, which frequently is the case.

The third would be that the underground mechanism needs absolutely no care and the services of a man, together with the usual repairs necessary to steam pumps, are eliminated. Further, the pumps are entirely under control from the engine room, and the engineer is at any time in a position to start and stop them, or vary the amount of water pumped within the limits of the system.

Fourth, in the case of flooding, where a steam pump would be out of commission, the Elmo Harris Return-Air System will operate at even increased efficiency, depending upon the head under which the tanks are submerged.

The fifth argument would be that any solid matter capable of passing through the water pipes could be pumped so that no clogging of the parts would occur in the event of dirt or other foreign substances getting into the sump.

In some mines the question of electric pumping may have been considered. The introduction of electricity into a mine is a constant source of expense and in some cases of danger. The actual cost of pumping will be in excess of the Elmo Harris Return-Air System, and the chances of failure of a more or less complex mechanism underground where the conditions are known to be none too good are points against the adoption of electric pumping.

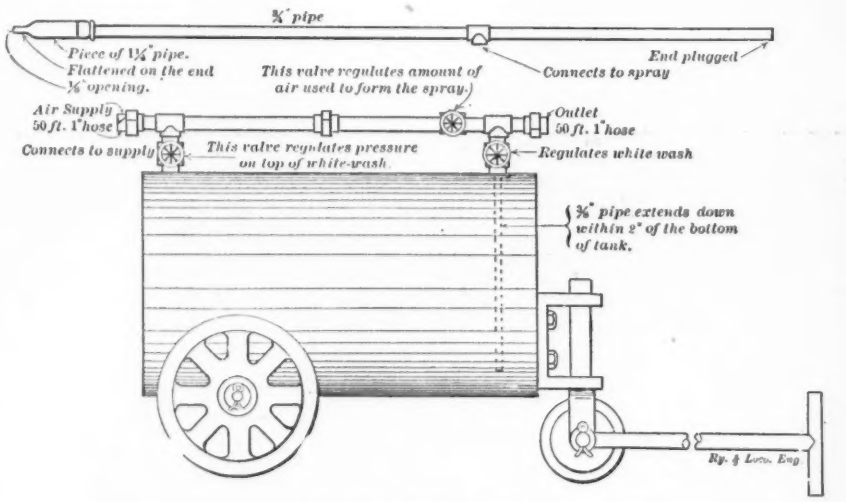
Further, in the case of flooding, the electric power would be entirely out of commission, and even the ordinary drip of the mine, if it reached the motor parts, would cause trouble.

All of these points are worthy of most careful investigation. The saving resulting both from the use of high duty compressors and from improved methods of pumping, is too great to be lightly considered, especially as it is evident that the introduction of high grade machines does not involve a sacrifice of the present compressor equipment.

A. W. PATTERSON, JR.

Air Whitewasher.

A whitewasher operated by compressed air, says a correspondent of *Locomotive Engineering*, accomplishes in two hours an amount of work that would keep one man busy a month. The construction of the machine is fully explained in the illustration.


¾" pipe
Piece of 1¼" pipe. Flattened on the end ⅛" opening.
This valve regulates amount of air used to form the spray.
End plugged
Connects to spray
Air Supply 50 ft. 1" hose
Connects to supply
This valve regulates pressure on top of white-wash
Outlet 50 ft. 1" hose
Regulates white wash
⅜" pipe extends down within 2" of the bottom of tank.
Ry. & Loco. Eng.

AN AIR WHITEWASHER.

The Air Power Plant of the Modern Mine.*

The prevailing tendency in modern mining is toward a greater operating economy, and in the effort to reach higher efficiency the air-power plant of the mine is receiving greater consideration. Compressed air has long been recognized as essential in mine operation, but it is only within comparatively recent years that it has been credited with any degree of economy. Its use, up to that time, was looked upon merely as an instance in which efficiency could well be sacrificed to expediency.

This fallacy owed its origin to the truly disgraceful performance of some of the air-power plants of a decade or so ago. These were in most cases installed by inexperienced men, ignorant of the first principles of pneumatic practice; for pneumatic science was then new. Or, if not inexperienced, the engineers were handicapped by a mistaken economy which forbade an adequate expenditure for correct plant design, good air machinery and good distribution systems. Furthermore, a compressor installed primarily to run a limited number of rock drills was forced to carry an increased number; just as likely, an old steam pump or an out-of-date hoist was also connected to the air line. Then, when fuel bills assumed alarming proportions and the compressor fairly groaned under its overload, the manager promptly laid the blame upon compressed air and pronounced upon it the curse of extravagance.

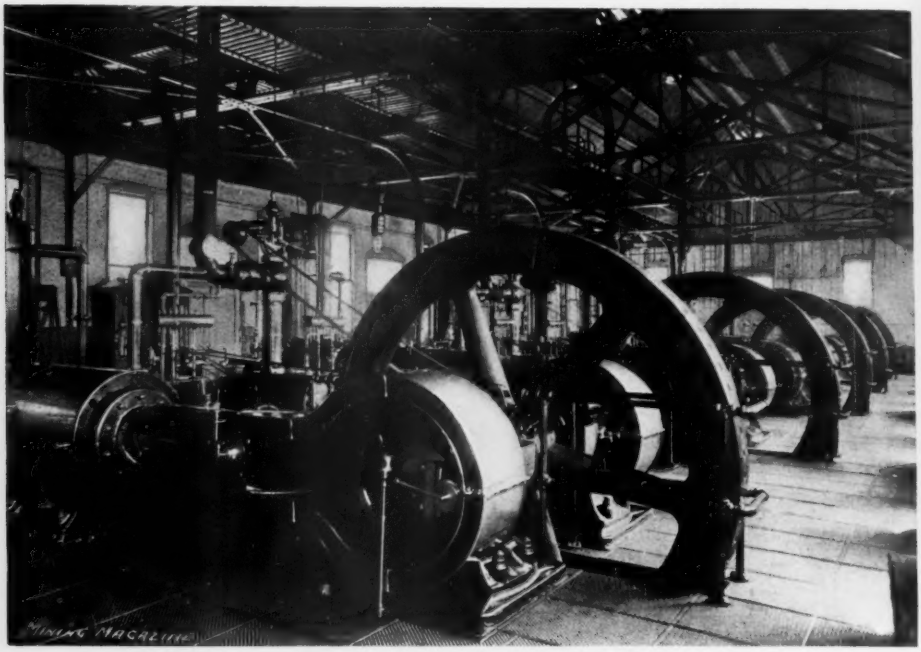
Be it here noted, however, that even in these extreme cases the air-power plant was retained. In spite of all the excessive costs fairly or unfairly charged against it, compressed air continued to be used. Why? Simply because there

* By Lucius I. Wightman, in the *Mining Magazine*.

was no other power that could take its place and do its work; and this is as true to-day as it was twenty years ago.

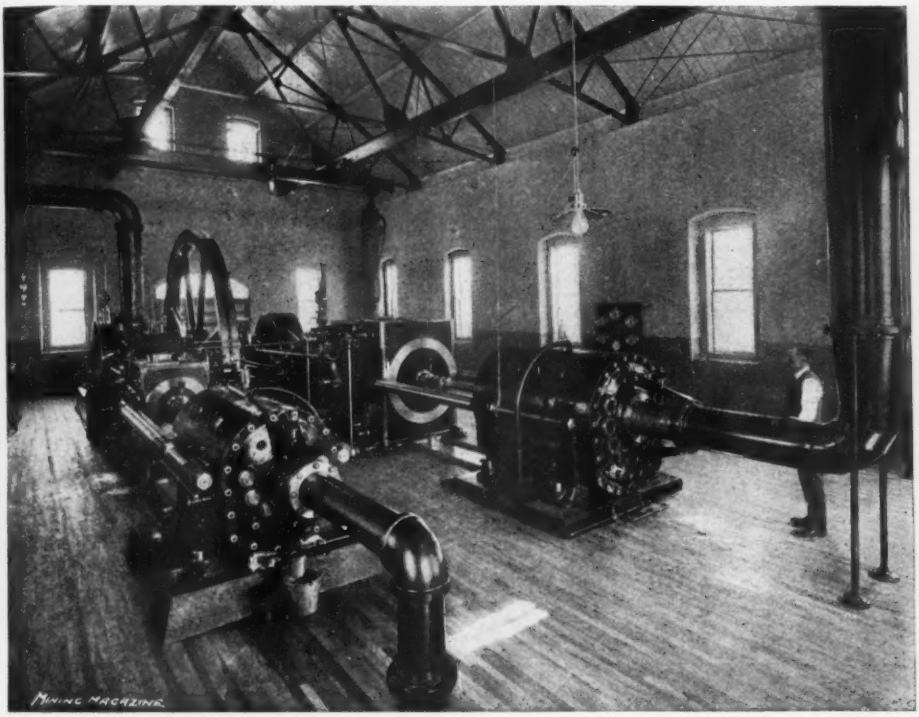
The place of air power in mining practice being, then, firmly established, the problem confronting the manager and engineer of the modern mine is the design and installation of an air-power plant which will not only do its work, but will do it at the least possible cost. There is nothing out of the ordinary in the design of a compressed air system. The basic principles of power-plant design are the same, whatever the power adopted. The correct arrangement of an air-power system lies simply in the application of well-understood rules to certain special conditions. Let it be stated at this point that, where operating economy is the ultimate object, first cost should have a secondary place. The difference in price between a good power equipment and a poor one is simply a premium paid on a guaranteed assurance of sustained satisfactory performance. Subsequent recommendations are made with this idea in mind.

First in the list of power-plant elements comes the boiler equipment. Fuel at the average mine is high-priced and fuel saving is naturally the first economy. As between the old reliable return-tubular boiler and the more modern water-tube type, the difference in evaporative performance is so slight as to be negligible, assuming conditions to be the same in both cases. But the latter has other advantages, which cannot be ignored. Its cost per horse-power, including settings, is less than that of the older type. It gives a greater boiler capacity for a given space than the return-tube pattern, and space is often a consideration in mining work. It is a



BATTERY OF SEVEN CROSS COMPOUND STEAM AND AIR AIR COMPRESSORS AT THE MINES OF THE CAMBRIA STEEL COMPANY, JOHNSTOWN, PA.

built-up structure and may be shipped, if necessary, in comparatively small sections, even to the most inaccessible locations—another interesting feature of mine requirements. Mine service is apt to be hard on boiler tubes, for the water is usually bad, often very bad. The water-tube boiler is more easily cleaned and its tubes more cheaply replaced, fluence on plant economy, as it will safely sustain higher pressures than the return-tube type, particularly in large sizes. The effect of high pressures on fuel consumption is best demonstrated by the consideration of a hypothetical case which may at any time arise in actual practice. Assume a boiler of moderate horse-power rating, which,

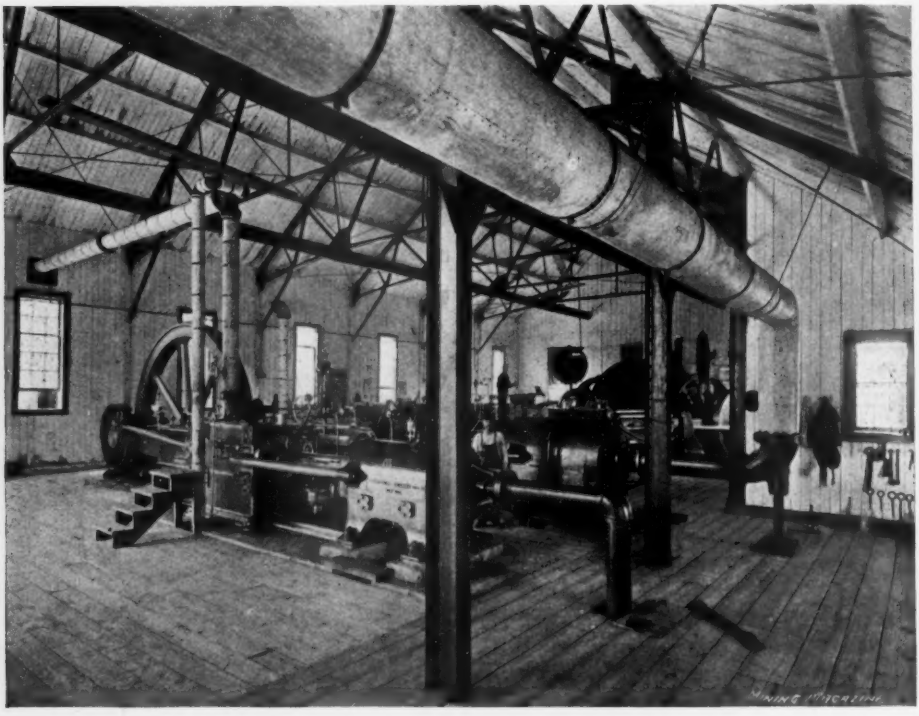


CROSS COMPOUND CONDENSING TWO-STAGE CORLISS AIR COMPRESSORS AT THE MOHAWK MINE, CALUMET, MICH.

than is the case with the return-tube type. Herein does the type of boiler affect in some degree the fuel consumption, since evaporation efficiency depends upon the condition of the tubes. The water-tube boiler is more apt to be kept in a condition of high efficiency.

But it is in the matter of pressure that the water-tube boiler has its greatest in- with feed water at 200 degrees Fahr. and pressure of 100 pounds gauge, shows a factor of evaporation of 1.0523 and evaporates 8 pounds of water per pound of coal. Under similar conditions, but with a pressure of 50 pounds gauge, the factor of evaporation becomes 1.0611, indicating that .88 of 1 per cent. more fuel will be burned per pound of water

evaporated in producing this higher pressure. This difference is so small that it may be neglected, and 8 pounds of water per pound of coal may be taken as the evaporation in both instances. Assume now an engine with a cylinder 24 inches in diameter and a piston speed of 400 feet per min. With a cut-off of 75 per cent. and an initial pressure of 100 pounds gauge, operating



CROSS COMPOUND STEAM AND AIR CORLISS AIR COMPRESSOR AT THE MICHIGAN MINE, ROCKLAND, MICH.

non-condensing, the M. E. P. is 96.64 pounds and its theoretical steam consumption 14,580 pounds per hour. Now take the same engine under initial pressure of 150 pounds gauge. A cut-off of 31.2 per cent. is found to give a M. E. P. of 96.54 pounds non-condensing, practically equivalent to that in the first instance. But in the latter case the theoretical steam consumption is 8,511 pounds per hour. Taking 8 pounds of steam per pound of fuel burned, the coal consumed in the first case, at a pressure of 100 pounds gauge, amounts to 1,822 pounds per hour. In the second case, at 150 pounds pressure, 1,064 pounds of coal are consumed. The use of the higher pressure in this case theoretically saves 758 pounds of coal per hour, with the engine doing practically the same work. While the actual steam and fuel consumption would be greater in practice by perhaps 25 or even 50 per cent., yet the relative values would remain about the same, the percentage of saving decreasing somewhat. In any case, the water-tube boiler, in permitting higher pressures, effects a very material fuel saving.

The size of the boiler units has an

effect on plant economy. Generally speaking, two large boilers are better than three smaller ones of equivalent total capacity. Not only is the cost of setting less in the former case, but there is also less radiation, and less likelihood of air leakage above the grate.

In the matter of steam auxiliaries and piping, standard practice must be followed. It should always be remembered that economy is the end sought and high-grade construction alone can guarantee continuity of service and efficient performance.

Condensing water is a blessing not usually granted the mine plant, but it should certainly be made use of where available. A vacuum of 26 inches is approximately equivalent to an increase of 12 pounds in M. E. P. In the case already cited, such a vacuum with 100 pounds of steam and 75 per cent. cut-off would have produced an increase of power of 11.2 per cent.; with 150 pounds of steam and 31 per cent. cut-off, the increase would have been 11.5 per cent. Putting it differently, the same power would have been secured, condensing, with a corresponding reduction in fuel burned; and when fuel is costly, condensation certainly pays.

Auxiliaries peculiar to the air-power plant are the circulating pumps for compressor jackets and intercoolers. These should be adequate, since the failure of circulating water may permit compressor temperatures to run up to ruinous values, throwing heavy overloads on the engine, sacrificing compression economy and producing ideal conditions for an explosion in the air chambers. In some large plants three pumps are installed side by side in the boiler room. One handles boiler feed, another, circulating water, while the third is a reserve for either of the others, the piping being so arranged that all three are interchangeable in their functions. This is an excellent arrangement, giving all the protection necessary, with a saving of one pump.

The heating of feed water is an important factor in power-plant economy. Heating to 200 degrees Fahr. is equivalent to a saving in fuel of 12 to 15 per cent., compared with the use of cold feed water. As between the closed and open type of exhaust heater there is little difference in efficiency provided the water is pure. The former has the advantage of avoiding the pumping of hot water. But the feed water available in a mining camp is seldom pure and the closed type is likely to suffer seriously as a result. The open heater has a distinct advantage in this case, acting as a purifier in throwing down in solid form most of the impurities which are precipitated at the temperature of exhaust steam. It has the further advantage of saving the condensed steam and returning it to the boilers as pure water. Where the water is very bad, it is quite possible that a live steam purifier will pay for itself many times over in the boiler repairs saved. In condensing plants of any magnitude, a primary heater of the closed type should be introduced between engine and condenser, not only heating the feed to, say, 150 degrees Fahr., but also aiding the condensation. A secondary heater, taking water from the primary, will receive the exhaust from all auxiliaries, raising the feed temperature to 210 degrees or 212 degrees Fahr. Right here may be emphasized the importance of using all the exhaust steam, not only from the main units but from all auxiliaries as well.

The logical sequence of the power cycle brings us now to the air compressor equipment, the heart of the air-power plant. The apparatus thus far discussed has been that involved in the economical production of steam. It is the function of the air compressor to take this steam and convert it, with the least possible loss, into the energy of compressed air. Of the making of air compressors there is no end, and the selection of a type is a weariness to the mine manager. The problem may be simplified by adopting a broad classification into straight-line and duplex types, for practically all modern compressors can be referred to one or the other of these divisions.

The straight-line type possesses the three advantages of simplicity, compactness and ease of installation. Frictional losses being very low, the mechanical efficiency of the good straight-line compressor is high. At or near full load, with cut-off valves, it may have a good steam economy. But there are features to be considered on the other side of the question. With fairly high air and steam pressure the straight-line machine

will not run slow on shortened cut-off. The energy in the flywheel is not sufficient to carry it over centres, and to avoid entire stoppage there are two alternatives. Either the cut-off must be lengthened to give sufficient power to run at low speed, in which case there is a great waste of steam when the machine speeds up under increasing load, or economically self-regulating below 35 or 40 per cent. of full load.

Compounding the steam end of a straight-line compressor is not economically practicable under varying load, inasmuch as the very expansion of the steam sought by compounding prevents running at low speed, for the reasons already stated. The "double-compound"

CORLISS CONDENSING COMPRESSOR WITH CROSS COMPOUND STEAM AND AIR CYLINDERS AT THE ATLANTIC MINE, ATLANTIC, MICH.

there must be a certain fixed limit below which speed must not fall, and the excess air compressed when the load falls below this limit will blow off through the relief valve. In either case there is a direct and serious loss of power; in the first, a waste of steam, in the second, a waste of steam and air. The straight-line compressor cannot be considered straight-line compressor at economical cut-off is to all intents a constant-speed machine, in which the air wasted at the relief valve when the compressor runs underloaded offsets the improved steam economy at full load.

To sum up for the straight-line compressor: It is a good machine in moderate sizes, for moderate pressures, under

fairly constant loads, where the very highest steam economy is not a vital essential. For mining plants of a semi-temporary nature or pending the establishment of a permanent paying basis of operation, it is a convenient, reliable and satisfactory machine. But where the highest fuel and steam economy is necessary in plants of large capacity, more refined compressor types are preferred.

Turning now to the compressors of the duplex type, we find a balanced design, in which the cranks at 90 degrees equalize the strains and reduce the extremes. On one side, maximum power may encounter minimum resistance, and a half revolution later, minimum power is applied to maximum resistance, as in the straight-line type. But on the other side, at these instants pistons are at mid-stroke and the second steam cylinder aids the first at the time when it most needs assistance, and is in turn assisted half a revolution later. This in brief is the principle of duplex construction. Properly designed and properly installed, the mechanical efficiency of the duplex will be but little, if any, inferior to that of machines of the other type. Some modern duplex compressors of large capacity are now made with a solid sub-base which makes them a unit of perfect rigidity, and reduces installation to the simplicity hitherto characteristic of the straight-line type alone.

In the matter of regulation, the duplex compressor has an unquestionable advantage over the other type. The angular crank arrangement and the mutual assistance of the two steam cylinders permit the very lowest speeds to be maintained without stopping. A good duplex, underloaded, will run so slowly as barely to turn over, but when the load is increased it instantly speeds up to meet the demands. It does this, be it here noted, without any change in the cut-off. It has the same steam expansion at low speeds as at high ones and steam is thus used economically over the full range of load. The extremely small load which the duplex type of compression handles successfully, avoids the loss of compressed air at the relief valve. This feature alone is of great importance in its bearing upon air-plant economy.

But it is in the compound machine that the duplex type shines with especial brilliance, as compounding on either steam or air end, or on both, is secured without any increase in the number of working parts. The advantage of compounding steam and air cylinders will later be considered more fully. But it is to be noted here that in the duplex type the full advantage of compounding the steam cylinders is obtained over the whole range of load. A cross-compound steam and air compressor is just as completely self-regulating as a duplex steam and air machine. Compounding, therefore, in a duplex type not only saves steam directly by complete expansion, but also indirectly by avoiding the loss of air pressure at the relief valve. The special feature of excellence of the duplex type to be noted here is that it secures this full advantage of "double-compounding" over the entire load range, without any added complication.

Against the duplex compressor it may be urged that its design makes the foundation a part of the machine itself, and a poor foundation may ruin the mechanical efficiency of the unit, while a high-class foundation is expensive. The adoption of a sub-base in duplex machines of even large size has removed this objection. Such a high-grade mechanism as a large air compressor in any case deserves a suitable foundation and the utmost care in lining up and setting.

To briefly review the case for the duplex compressor, it is distinctly the machine for high-grade, permanent plants of large or moderate size and modern high pressure, working under wide variations of load, in conditions which make fuel and water economy imperative.

It is unnecessary, in the present understanding of pneumatic practice, to argue long on the advisability of compound compression, as compared to single-stage work. The question is no longer open to any extended discussion. The almost universally accepted idea to-day is that, for pressures of 70 pounds or less, the increased complexity of the compound air compressor impairs the economic value of compounding—with a possible exception in favor of the duplex machine. For pressures of 75 pounds and upward, multi-stage compression is certainly an added economy and the fuel saving obtained thereby may amount to 10 to 15 per cent. Th

requirements of ordinary mine work will seldom call for pressures which cannot be efficiently produced in two stages, but where pneumatic haulage is used, the higher pressures for locomotive storage-tanks will demand three or even four-stage compression.

Stage compression depends for its effectiveness upon the efficiency of the cooling apparatus employed. Cylinder jacketing is, of course, imperative, but it is more important, from an economic standpoint, to jacket the heads of the cylinders than the barrels. This keeps the valves cool and admits air through cold passages. Intercoolers between cylinders should be of the very best design and they cannot be held adequate to their work if they fail to reduce the air temperature to within 10 degrees of the water temperature. This calls not only for ample cooling surface and complete subdivision of the entering volume of hot air from the L. P. cylinder, but also for cold water and plenty of it.

Needless to say, provision should be made for supplying air as cool as possible to the compressor intake. It should never be drawn from the engine room, but from a cool, outside location, and the intake conduit should not be more exposed to heat than necessary. A reduction of 5 degrees in intake temperature is equivalent to a 1 per cent. increase in compression efficiency. Clean air also is highly desirable, and where the atmosphere is filled with flying dust from a mill or crusher, an air washer on the intake will save valves, seats and cylinder bores.

The question of compounding the steam end of the air compressor may not be so readily decided as the question of compound compression, but in reality the saving by high steam expansion will often be three or four times that secured by stage compression. The use of the high steam pressure prevalent to-day has been made possible by compound steam engines. In the case of the engine discussed earlier in this paper, a cut-off of 31.2 per cent. with 150 pounds initial pressure was found to give a M. E. P. equivalent to that secured on 75 per cent. cut-off at 100 pounds initial pressure. But such a short cut-off is out of the question in a single steam cylinder, as already noted. In all probability this case would be handled by compounding the steam end of a duplex compressor, and this high expansion could thus be taken advantage of even at the lightest loads. High steam pressure, compounded steam and air cylinders, and duplex design thus combine to keep the fuel consumption per cubic foot of air compressed not only at the lowest figure, but practically constant, regardless of the load. The principle which primarily makes this possible is a principle peculiar to air compressors. Whatever the speed, the load per stroke on the pistons is constant. Governing is secured not by changing the cut-off (except in Corliss types) but by changing the speed; and this brings us logically to a consideration of compressor governors.

Standard practice advocates a combination regulator embodying fly-ball action and direct air pressure. The fly-balls limit the speed to a certain maximum. The direct-pressure element cuts down the speed as pressure rises under reduced air consumption. When the pressure falls below a certain limit, the machine speeds up automatically. Where the valve gear is of the Meyer or other dependent type, governing is secured by throttling the steam supply. In compressors with Corliss valves the governor changes the cut-off just enough to change the speed, but the alteration is not sufficient to seriously affect the steam economy.

Aftercoolers are an important feature of an air-power plant where the air is to be used with any degree of expansion. They may be adopted, even in the average mine plant where drills constitute the largest part of the load; and where trouble is experienced from freezing up of exhaust ports, as when the air is used in pumps or hoists, there can be no more certain remedy than the introduction of an aftercooler close to the compressor which will precipitate the larger part of the moisture entrained in the air, before it can enter the line. Needless to say, large cooling surface and plenty of cold water are essential to successful aftercoolers, and unless the air chamber is regularly drained, the device fails of its very object.

Receivers are a necessary part of the air-power plant. They may be of plain tank form or, better yet, of the "receiver-intercooler" type, combining the functions of air reservoir and air cooler. There is no real limit to the amount of receiver

capacity a plant may have. But it is wholly wrong to look upon the receiver as a power reserve, a source of energy. It is not; rather is it an elastic cushion in the air system between the rapidly pulsating compressor discharge and the widely fluctuating air demand. It equalizes efforts and makes things easier on the entire arrangement.

The question of the best air pressure to employ is ever open to discussion among mining men. Common practice seems to favor pressures of from 75 to 100 pounds. In the majority of cases the lower pressure is preferred, but there is a pronounced tendency toward the higher limit in the larger mines. The value of pressures above 100 pounds may well be questioned, for while the drill is undoubtedly more effective as a rock cutter at higher pressures, it is also subjected to much more severe service, with increased liability to injury. But the breaking limit of the steels will be reached before the drill itself gives out. The real limit of pressure is fixed by the drill runner, who will not stand pressures so high as to make handling his machine disagreeable to himself. He will simply throttle high pressure to relieve himself and thus lose all the expected advantage. There have been instances—as in running a tunnel in record time—where air has been used at 135 and even 150 pounds. But in these cases the runners have been spurred on by a possible bonus. At ordinary day rates, the average drill man will not stand for more than 100 pounds of air.

If by the term "air-power plant" we limit ourselves to the power-producing arrangements, discussion may be closed here. But it may be well, in this case, to add a few words as to the power distribution. The question can be briefly disposed of; the secret of an economical air-distribution system lies in a pipe line of ample size and careful workmanship. Gains by the utmost refinement of power-plant design may be entirely offset by a leaky, insufficient system of piping. The line should be properly supported against sagging or creeping, and expansion and contraction must be provided for, best, perhaps, by offset joints at intervals. Flange joints are better than screw joints. Gate valves are better than globe valves; rising-stem valves show the degree of opening at a glance. Every low place in the line must have a drain; more important still, this drain must be regularly opened and the condensed water removed. A pipe system laid on top of the ground will probably last longer than if buried, and it has the further advantage of being always open to inspection. Leaks must not be tolerated. The power equivalent of a good quantity of coal may be wasted through a leak which can be detected only by the use of soapy water. It is well to have gauge connections on the line, for frequent tests for pressure drop.

In conclusion, let it be said that the foregoing remarks are based fundamentally on economy—not cheapness, but economy. It is presumed that the mine justifies a reasonable outlay as a paying business proposition. Prosperity depends upon getting out the ore at the least cost, and time means money. A failure of air pressure in the mine, due to a breakdown in the power system, may so upset a schedule of operation as to cause a loss greater than the cost of the power plant itself. Every delay represents a loss, when every drill out of operation means two idle men in the crew, when the failure of pressure at a hoist may disorganize a whole gang of trammers, when the shutting down of a pump may mean the flooding of lower levels.

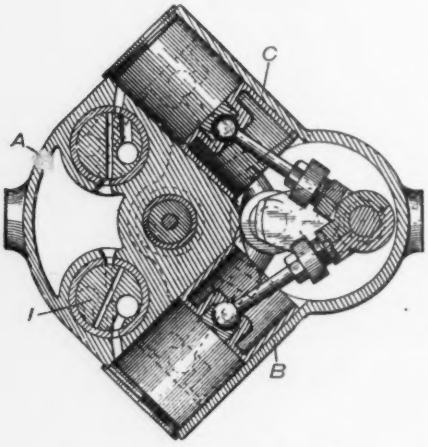
More and more is air power entering into the very heart of mine operation. More and more is successful mining coming to depend upon the economical production, maintenance and application of air pressure. In the light of these facts, a generous outlay for correct modern plant design and the most improved air-power equipment is not an extravagance, but rather an example of that higher, truer economy which sees beyond first cost to the savings secured by an investment intelligently directed in applications of the best methods.

Portable Pneumatic Motor.

The principal feature of this invention is embraced in the construction and arrangement of the valves for controlling the admission of the compressed air to and its escape from the power cylinders *B* and *C*. The valves embrace oscillating plugs or cylinders *I*, which are adapted to turn in cylindrical seats or chambers in the main casing *A* and are arranged with their axes of rotation transverse with the

cylinders *B* and *C*, each of the oscillating valves being arranged to operate in connection with one of the cylinders. Each valve and the cylindrical seat has two sets of co-acting valve ports or passages located one set at each end of the valve and seat and opposite the cylinders with which the ports or passages constituting the set are associated.

The illustration shows the relation of the two valves with respect to the pistons in one position of the crank shaft, the right-hand piston has just started on its outward stroke, and the valve ports are in position to exhaust the charge. The left-hand piston is just completing its inward



PORTABLE PNEUMATIC MOTOR.

stroke, and its valve ports are in position to cut off the supply of air and will be immediately in position to exhaust the air from the cylinder.

An important advantage claimed for the general arrangement of the valve, in which the supply chamber of the compressed air is located between the cylinders, is that the passages leading from the supply chamber to the valves and from the valves to the cylinder are made very short, being in the case of the passage from the supply chamber to the valve seats merely slots or openings in the walls of the valve chamber which separate the latter from the supply cylinder.

Reinhold A. Norling is the inventor.—*The Engineer.*

Apparatus for Supplying Air to Submarine Torpedo Boats.

A shocking accident which caused the death of twelve men occurred on July 6th in the bay of Bizerte, a port of Northern Tunisia.

The "Farfadet," a new French submarine torpedo-boat, about 9 feet diameter, 125 feet long, and 185 tons displacement, was given orders to plunge and while doing so, for some unknown cause, the hatchway door of the forward water-tight compartment failed to close, and the "Farfadet" sunk head-first in 60 feet of water.

A French man-of-war and several steamers in the port of Bizerte took immediate steps to float the boat and sent divers down to attach chains around the "Farfadet" to hoist her.

Three attempts were made, but the hoisting apparatus broke each time and, after 36 hours, the rescue was abandoned and a large man-of-war was telegraphed for.

In the meantime, the twelve men which were imprisoned in the steel coffin were communicating with the divers by means of the Morse code, hammering on the shell; they asked for air telling that they could not last long, in fact after some 40 hours all signals stopped, as life was extinct.

About a week after the accident, a man-of-war lifted the "Farfadet" and the corpses of the twelve unfortunate marines were found.

It seems to be beyond the conception of any human being that no effort was made to give the imprisoned men a sufficient supply of air to enable them to live until they could be saved, and the occurrence ought to be qualified as criminal ignorance.

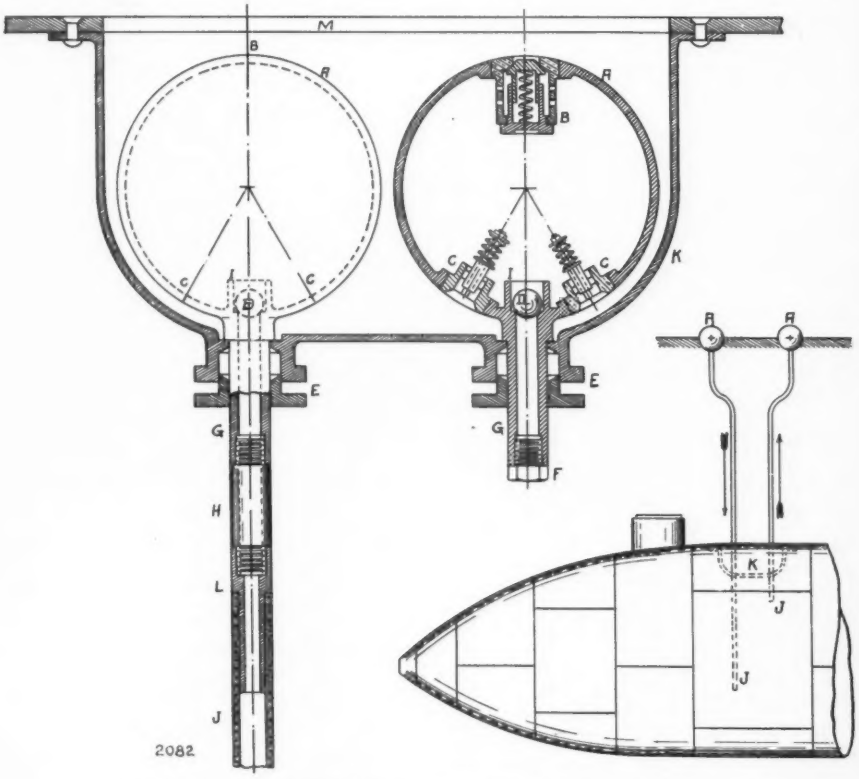
Inasmuch as the "Farfadet" had sunk in only 60 feet of water and as she was within access to the divers, it would have been very easy to drill two holes, say for ¾-inch pipe, into the 1¼-inch shell. These holes could have been tapped in a few minutes, and a nipple with valve attached to each. The amount of water which would have entered the boat during the operation would have been insignificant and could have been disposed of with any hand pump.

Then a ¾-inch 5 or 6 ply rubber hose lowered from the surface should have

been connected to each valve. By means of any ordinary air pump, whether operated by hand or by power, air could have been supplied to one hose at a very light pressure and the foul air would have found its way to the atmosphere through the other hose. Thus twelve men lost their lives on account of absolute lack of sense of their would-be rescuers.

The apparatus consists of a metallic case or shell *K* riveted to the shell *M* of the boat in such a manner as not to interfere with the speed or movements of the boat, this shell *K* would be about 12 inches wide, 12 inches deep and 24 inches long; it would be fitted with two stuffing boxes *E* about 1¾ inches bore.

Two metallic hollow balls *A A*, about 11 inches in diameter each, with 1¾-inch



APPARATUS FOR SUPPLYING AIR TO SUBMARINE TORPEDO BOATS.

Should the above device have been resorted to, the men would probably have lived for weeks in their precarious position.

In order to avoid the recurrence of such unfortunate mishap, a small air-supplying device, as per cut, ought to be installed on each submarine boat.

necks *G*, would be located in the shell *K* and would each be fitted with one or more inlet valves *B* on top and discharge valves *C* near the bottom; a small hollow ball *D*, say, 1¼-inch diameter and of gravity 2, would be placed in the neck *I* and act as a check valve.

H is a right and left-hand coupling

for connecting the neck *G* to the piece *L*, which is rigidly attached to a piece of 1-inch inside diameter wire-inserted rubber hose 1¾-inch outside diameter; this hose ought to be graduated in feet.

F is a plug which is at all times screwed on the neck *G* and which must be removed only in case of accident.

It will be seen that everything connected with the necks *G G* of balls *A A* being of the same outside diameter, say, 1¾ inches, it will be easy to slide the hose through the stuffing box *E*.

Should an accident occur or should it be necessary to dive for a great length of time, on account of being pursued by the enemy, the operation of the apparatus would be as follows:

First, note the depth by consulting the gauge, then unscrew the two plugs *F F* and attach rigidly the couplings *H H* and the two lengths of hose *J J*.

Loosen slightly the stuffing boxes *E E* and attach either of the hose *J* to an ordinary hand air pump capable of overcoming the water pressure.

As the balls *A A* are naturally filled with water, it is necessary to fill them with air to make them float, and for this the hand air pump will be quickly operated for a few seconds, and will cause the ball check valve *D* to leave its seat and to drop outside of its guide into the ball *A*. While the pumping continues the hose *J* connected with the air pump will be forced up through the stuffing box *E* until it reaches the surface and floats; the pump will then be attached to the second hose and the same operation performed, but instead of obtaining the air from the interior of the boat its suction will be attached to the first hose and air will be pumped from the atmosphere.

As soon as the second ball floats disconnect the pump discharge and the second hose will be an atmospheric discharge pipe, while the first one will act as a suction pipe and the pump will discharge the air into the interior of the boat, giving a constant supply of fresh air.

The air pressure inside of the boat will naturally be about 3 or 4 pounds above the atmosphere—that means such additional pressure as may be required to overcome the tension of the valve springs.

As the balls *A* will remain practically in a vertical position when floating, only a very small amount of water will enter the hose through the valves *B*, and this small quantity of water, as well as that which has leaked through the stuffing boxes *E E* while the pipes and hose were forced up, can easily be taken care of by means of a small hand pump.

Should it be found advisable to protect the balls *A A*, a sliding cover operated from the inside by a crank or lever could be easily installed so as to cover the opening *M*.

F. SCHMERBER.

The Coming Motive Power.*

Many and marvelous are the inventions that have grown out of electrical discoveries and research, until it seems, from their multiplicity and present state of perfection, that the spirit of invention which animated these creations must soon slumber. Mighty, indeed, has been the revolution in the affairs of man wrought by electricity, under the command of a genius, even though its march has been in the wake of that other potent force in civilization—steam. Notwithstanding these achievements, the commercial and industrial world is fast becoming conscious of the fact that its future rapid strides and ultimate commercial supremacy, as a motive power, will depend on cheapening the production of this form of energy, so as to oust steam, which feeds wastefully on costly coal. Of course in the past few years hydro-electric generation has greatly increased the economy of production and long-distance transmission has become so much more perfected that the world has become fascinated by its conquests, till now the impression prevails that electricity must necessarily become the motive power of the age. The writer does not claim that this, the above tendency, is a false one, but simply is set forth to show the reasons why other available forces in nature have received so little attention and consideration. Among these neglected forces compressed air may be mentioned as a means of power transmission that has not received the attention that it deserves.

The application of compressed air to industrial purposes dates from the close

*By Joseph W. Buell in *Mineral Wealth.*

of the last century, although before this we find isolated attempts were made to apply it in a variety of ways.

To the fertile brain of Dr. Papin of France we are indebted for the first suggestion of conveying parcels in a tube by compressed air, and he was the first to suggest the use of compressed air as a means of transmitting power. This distinguished Frenchman went to the expense of putting his ideas into wood and metal, but the results of his experiments were not encouraging. This was about A. D. 1700.

About 100 years later a Welsh engineer contrived an apparatus to utilize a water power to work a blast furnace and machinery, a mile and a half distant, by compressed air, but the resulting blast was feeble.

For a century or more water elevators operating by compressed air have been used in the mines at Chemnitz in Hungary. Vague descriptions of apparatus for using compressed air in the mechanical arts are found in early English patents and publications, but none, so far as known, were practically applied. In 1810, Medhurst, of England, patented means for conveying parcels by compressed air. There is no authentic record that this project was reduced to practice, and it stands simply as a mile post on the road to advancement of knowledge in this direction. In 1824, Vallance revived the idea of Medhurst. Contributions to this science were also made by such pioneers as Pinkus, Cleeg and Pilbrow.

In 1837 the Italian Government ordered experiments to establish the laws that govern air transmission, and improvements in methods and appliancees have followed, resulting in the practical use of air for tunneling, in conveying parcels in tubes, and that valuable adjunct to railway trains—the air-brake.

Along about 1857 an American, Dr. Gorrie exhibited in London and elsewhere cold-producing machines, in which air was compressed in one cylinder, cooled whilst compressing, and re-expended in another cylinder, in a manner to utilize its expansive force. In 1859 a company was formed in London and permanent pipes laid down for conveying parcels by air. These lines of pipes were extended in 1865. During the same year Ericsson operated eighty sewing machines by compressed air in a factory in New York.

Experimental sections of pneumatic dispatch tube for carrying passengers were built at Sydenham, England, and in New York in 1867. The line at Sydenham was one-third of a mile long and was transferred in fifty seconds with a pressure of two and one-quarter ounces per square inch. In 1872 Congress appropriated $15,000 for a pneumatic dispatch tube between the Capitol and the Government printing office in the city of Washington.

Other systems have been multiplied by telegraph and express companies in Vienna and Berlin. The Western Union Telegraph Company conveys messages from Lower Broadway to Twenty-third street in New York, a distance of about three miles. They employ a vacuum, and the parcel travels between the terminals ordinarily in five minutes. Air was used for rock drilling in tunneling Mount Cenis, Hoosac, Arlburg and other mountains. In 1879 air was used to propel cars on the Second Avenue Railroad, in New York.

This was briefly the state of the art up to 1880, but the dreams of Papin and the hopes of Medhurst were but partially realized. The disappointments of the past are, however, no cause for apprehension of the final successful application of air for transmitting power. Many of the grandest successes of the present were absolute failures in the early attempts. Previous to 1880 the waste of energy in the compression of air and the sickly design and faulty construction of the mechanism for using air, largely due to the ignorance of the principles of thermo-dynamics, retarded the introduction of air as a mode of transmitting power. At Mount Cenis tunnel the loss in compression was fully 90 per cent. In the modern compressors the loss is less than 16 per cent.

While compressed air has been used over and over again in a small way, and generally in a rough and uneconomical fashion, it was not until within a few years that any systematic attempt has been made to transmit and distribute this form of power for general consumption. To-day this is being successfully done in all large cities of both America and Europe, where the installations have given birth to applications and utilizations

for purposes heretofore unthought of, with valuable economic results, and a realization of high efficiency in its workings.

In Paris the power is distributed not only to factories and electric lighting stations, but also finds domestic use, being sold to householders, restaurant keepers, etc., keeping them supplied with an available power which is turned to account in many useful ways in producing the conveniences and comforts of life, while proving a welcome substitute for steam power, with its heat, smoke, danger and waste.

The commercial advantages derived from these air systems have resulted in their rapid extension, and in Paris elaborate provision is made to increase the size of the plant with a view of supplying an aggregate of 25,000 horse-power.

The general efficiency of this mode of transmitting power in these two systems is conservatively put at from 80 to 85 per cent., a showing that puts to flight the idea that transmission of compressed air over a distance of several miles necessarily entails enormous losses. The attainment of this efficiency is gained by the help of another physical agent in connection with the observance of certain simple laws, and an explanation in regard thereto may be readily understood without wading too deep into the water of science; and when understood will make clear the reasons why heretofore the progress in introduction of a power so rich in possibilities has been impeded, while the truth becomes apparent that there is very little loss of power through its transmission if properly manipulated. In order that the reader may understand the elements involved in the solution of this problem it is necessary to gain a few preliminary ideas as to the behavior of air under prescribed conditions. Air under compression when compelled to move in a certain path is governed by laws quite different from those affecting electricity. As the air flows through the pipes the resistance of the surface of the same has to be overcome, and whenever compressed air meets resistance the pressure falls slightly, but this moderate reduction in pressure does not involve a loss in transmission, because what the air loses in pressure it gains in volume, so that its mechanical effect may at any point be easily restored to its initial capacity by the application of a small amount of heat, and it has been found that by this simple expedient its capacity to do work at the points of consumption many miles from the power station is enhanced with but a nominal cost, and that no more economical effect of the application of heat has ever been found than this method of annihilating the effects due to friction in the air's transmission. An eminent English engineer declares that a quarter of a pound of coke per hour per indicated horsepower is sufficient to heat the air required in a moderate size engine. Nor does this fairly illustrate the economic value, when we come to consider that it is capable of another important service (as alluded to in Dr. Gorrie's discovery) at the points of consumption, in the use of the by-product, the exhaust from the motors—for the purpose of ventilation and refrigeration. In Paris the restaurants and beer cellars are supplied with refrigerant in this manner and which proves highly satisfactory in every respect and displaces the ice-melting method altogether, and in some places is so sought after for cold storage that power is consumed essentially for its exhaust to use to this end.

In this country compressed air is being pressed into service in every branch of industry, but the use to which the public is most familiar is probably in its application to railway trains in its adaptation to applying the brakes; but its utility and operation in this connection are scarcely appreciated until we come to consider the conditions of its use. While we have all noticed that trains cannot be gotten under way until the locomotive has run some distance, to work up speed, it is doubtful if we have ever stopped to think of the tremendous momentum that is being piled up as that speed increases and the energy that must be destroyed in bringing the train to a sudden stop after it has gotten under way. It is estimated that the vast amount of energy that must be called into action at a moment's notice is greater than can be imparted to a projectile by the largest of modern guns. Its triumph in this direction is daily evidenced, and it is the one important factor that has made speed in railway travel reconcilable with safety. How few of us have realized the importance of this daily performance? A train run-

ning forty miles an hour traverses 59 feet in a second—lurking danger appears in sight—the loss of one second through the lack of vigilance on the part of the engineer means its hastening on an errand of destruction by just 59 feet. By the touch of a lever the brakes are applied and the train that was rushing along at almost lightning speed is brought to a standstill in a minimum of time and within a distance of 400 feet from where the danger was sighted, and this prodigious power that is brought to bear on the brakes is so ingeniously distributed and applied as to relieve the cars of all strain, while the train is promptly arrested in its flight without creating any commotion among the passengers or giving rise to a disagreeable shock.

A Pneumatic Hoist.

A pneumatic hoist, designed by Mr. H. L. Pittock, manager of the *Oregonian*, Portland, Oregon, is illustrated on page 3912. This hoist was specially designed to meet the requirements of a new press, installed in the pressroom of the *Oregonian*. It is operated by the pressman, who has charge of the tensions and does not interfere with his duties there.

The hoist is operated by compressed air, which may be drawn from the mains in the building, or, if the pressroom is not regularly supplied with compressed air, a separate compressor and tank can be supplied, which would be driven direct from the drive shaft of the press.

The operation of the lift will be clearly seen by following the pipe (1) which carries air to the operating valves (2 and 3). By opening the valve (2) the main ram (5) is supplied with air through pipe (4), causing the piston (6) with its V-shaped platform to rise to the upper or lower roll brackets in a vertical position. When it is desired to bring the roll into position for running or placing paper upon the roll brackets for storage, valve (3) is opened, which admits air to the auxiliary ram (8) through pipe (7), forcing piston (9) to draw both ram (5) and piston (6) with its load into the press roll brackets, as shown by the dotted outline of the lift. To lower the main piston (6) the operating valve (2) is moved in a reverse direction, allowing the air in main ram (5) to exhaust into the atmosphere. To restore the main ram (5) to a vertical position, operating valve (3) is moved in a reverse direction, admitting air through the pipe (7a), exerting pressure on the opposite side of piston (9) and exhausting air to atmosphere from side previously used to bring ram (5) into position for discharging roll.

The flexibility of control is apparent, as by operating both valves (2 and 3) simultaneously the lift can be brought forward or backward and up and down at the same time, while returning either valve to a central position all movement of the rams is stopped. The operating valve levers are constructed to lock in a central position to avoid accidental starting of the list by contact with the levers.

The main ram (5) is connected with a trunnion plate (10) by means of a heavy steel pin (11), which allows the main ram (5) to move freely back and forth. The auxiliary ram (8) is also connected to a trunnion plate (12) located centrally to balance the same and take the weight of the ram (8) off the piston (9).

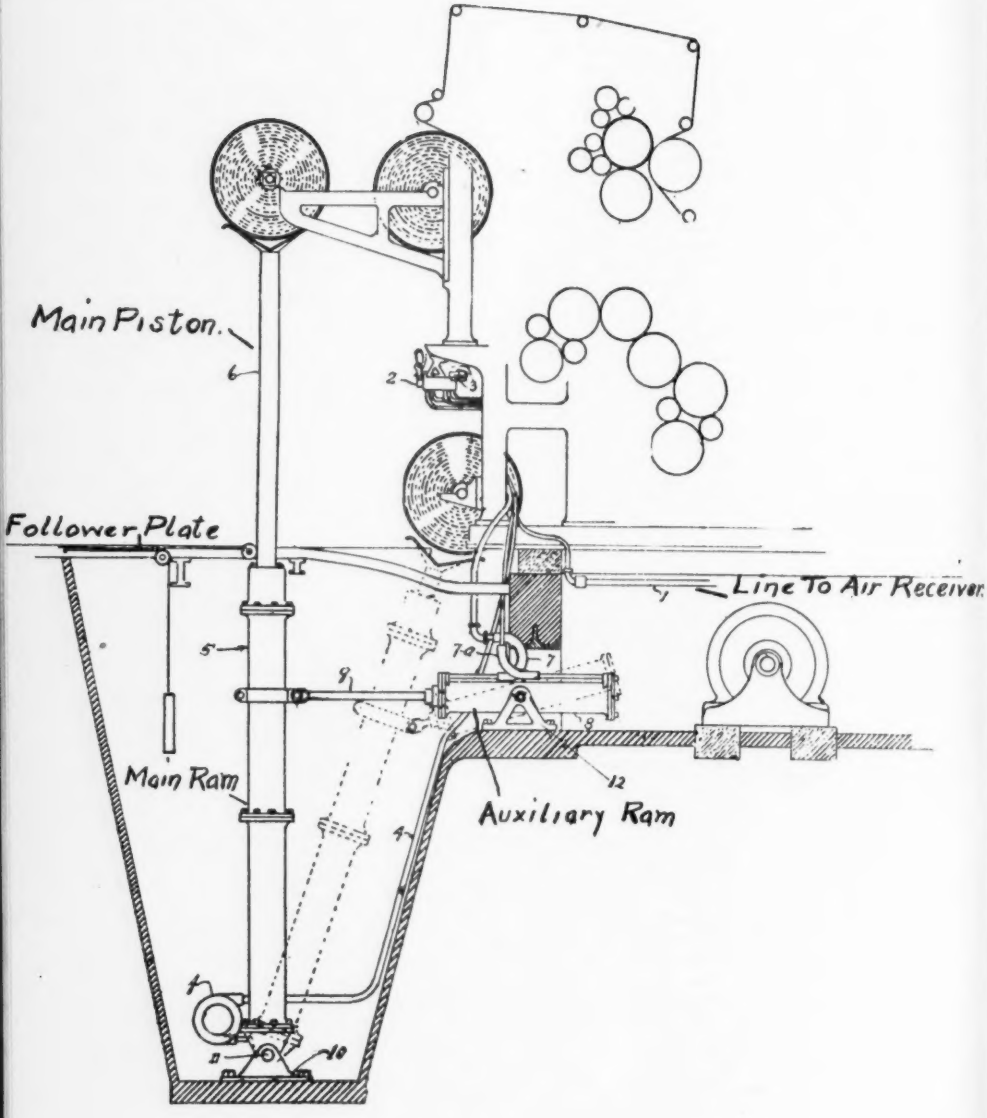
There are no valves, stops or movable parts whatever required in the operation of this hoist, except the operating valves, which are mounted in a neat and substantial valve box, conveniently located on the tension side of the press.

The advantage of this over all other methods of placing the rolls of paper on a press are:

Ease and safety of operation, as the hoist is controlled by two levers located between the lower and upper tensions, and the air valves automatically return to the centre, cutting off the air so that the hoist cannot accidentally injure itself or the press.

It is inexpensive to install, as it requires no expensive water connections and drainage, as in a hydraulic lift. It is a great saver of time in operation, as the tension man can take down the upper spindles without any assistance whatever, and place the rolls in the brasses. It puts in the lower roll as well as the upper ones.

Not the least of its advantages is its ability to take a roll out of the brasses, as at the close of a run a full four-page roll might be left on the upper brackets, with but very little used. The next time the press is plated it may be that only a three-quarter roll will be required on that bracket, when it would require the combined efforts of four or five men to get the large roll out of the brasses and down.



PNEUMATIC HOIST FOR LIFTING PAPER ROLLS IN A PRINTING PRESS.

With this hoist one man with the two little air-valve levers does the job with ease.

It occupies no room when not in use, as the V-shaped platform is moved down and forward under the lower roll, entirely out of the way, and the slot in the floor is automatically closed by a steel follower plate, so that it offers no obstruction whatever to trucking over or working around the press.

Its simplicity of construction makes the maintenance almost nothing. There are no valves or other parts about the cylinders to be adjusted, while the air-valves are specially constructed, self-seating and require no care.

Compressed Air Marking Machine.*

The drawings show a very practical application of compressed air to automatic machinery. The machine illustrated, while not having a very marked advantage over the press or the more commonly known types of marking machines, filled the particular requirements it was designed for in a highly satisfactory manner.

We had taken a contract to produce a large number of the pieces shown in Fig. 1 and had neither press nor marking machine, but had a fairly good compressed-air service and decided to make a marking tool that would let us out on our estimate safely. From the sectional side elevation and front view in Fig. 2 and the views to larger scale in Fig. 3 a general idea can be had of the construction and principle of operation. The air is supplied to valve *A* through tube *B*, this tube being flexible and connecting to the supply pipe below the bench on which the machine is designed to be fastened. This pipe has a globe valve (not shown) within easy access and is used to throttle the supply as needed. The tube *B* is connected to the valve case at *C*. The ports at each end of the valve case are connected by flexible tubes to the column in which the port holes leading to the marking wheel cylinder are drilled. These ports supply the marking-wheel cylinder, or head *D*, which has a vertical movement of about 9-16 inch. The piston *E* is fixed as shown, to frame *F*, while the cylinder moves, carrying the wheel to and from the work. The ports or supply passages are drilled through the piston and connect with the passages *G*, one going to the under side of the piston, the other to the top.

The table has a maximum travel of 3¼ inches, and is supported by and travels on a number of hardened rolls, bearing upon hardened faces attached to the under side of the table and the upper side of the knee. These rolls are retained in place by plates fastened on each side of the table. The stroke or travel of the table can be varied by adjusting the tappets *H* as required, and any speed of table travel can be obtained by throttling the air supply by the globe valve previously alluded to. The table is actuated by piston *I* in a cylinder which is cast integral with the knee, the piston rod extending from each end of cylinder and connecting with the table as shown at *J*, the one valve *A* furnishing air to both the table and marking-wheel cylinders simultaneously. The automatic reverse is effected by the tappets *H* striking end *K* of valve lever *L*, this lever having an excess of free motion before being acted upon by the spring *M*, which causes a quick reverse movement of the valve.

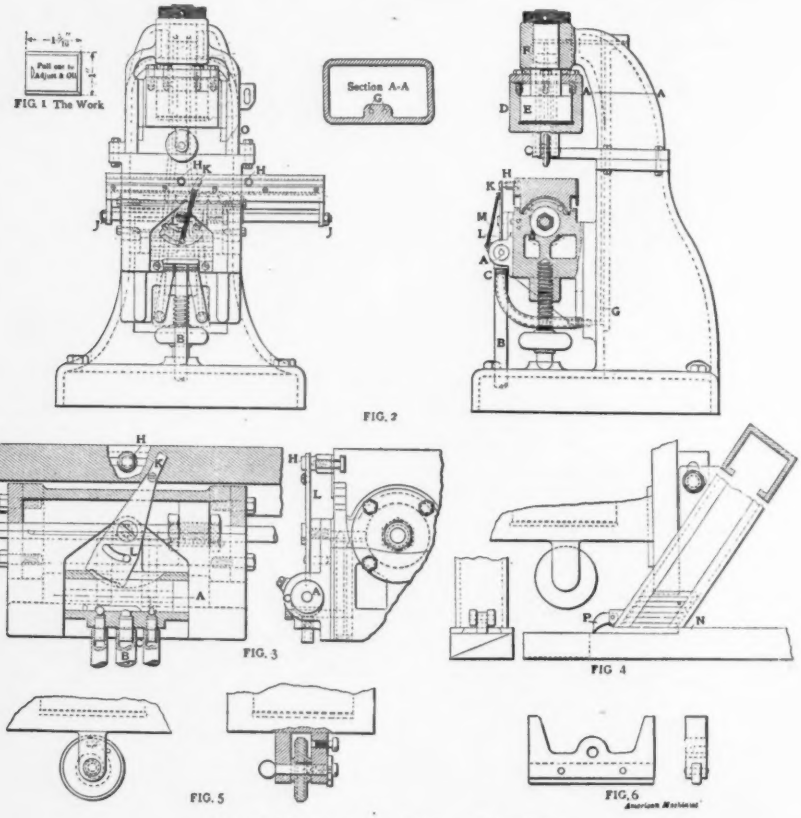
The larger sectional view in Fig. 3 shows clearly the valve and lever. The valve case is fastened to the front of the knee and the air passages are obtained by drilling. The exhaust takes place through the valve which is hollow. This view shows clearly the cylinder and piston for actuating the table, which has a vertical adjustment of 1¾ inches. A fixture employed for feeding the work is shown in Fig. 4 and consists of a plate fastened to the table and having a portion cut down from the top to a depth equal to the thickness of the work to be marked, as shown at *N*. The magazine is on an incline and fastened to the upper housing at *O*, Fig. 2. The magazine supports a pawl *P*, Fig. 4, at the lower front end, which engages with the work upon the return of the table and pushes it off on the inclined portion of the plate, from where it drops into a receptacle placed at the front side of the machine.

The operation is as follows: The plate travels with the table and under the magazine, the raised portion at *N* being of a length somewhat in excess of the required amount of travel necessary to allow the work to pass completely under the wheel, plus the width of the magazine.

*By H. J. White, in *American Machinist*.

The magazine rests flush with the raised portion of the plate and only one piece can get in position for feeding or marking upon every stroke of the table. Upon the plate reaching the loading point, air enters the right-hand end of the table cylinder and the lower end of the marking-wheel cylinder, thus forcing the table forward and the wheel down in position abutment of the piece against the shoulder of the work plate.

Fig. 5 shows the method employed to return the marking wheel to zero or the starting point. The wheel has a feather set in it and the spindle is splined to receive it. The spindle is drilled and tapped in the back end to receive a screw which is sawed through from the end to



COMPRESSED-AIR MARKING MACHINE.

at once. Returning, the air enters the left-hand end of the cylinder and the upper end of the wheel cylinder, raising the wheel and sending the table on the backward trip when the work is pushed off by pawl *P*. A spring (not shown) holds the pawl down and retards the work when the table moves forward, insuring an the under side of the head, forming a slot into which one end of a flat coil spring is inserted, the other end being fastened to the screw above it. A stop-pin in the wheel comes against the lug supporting the wheel spindle, as shown.

Fig. 6 shows a holder for a die made for marking round work that could be

rolled on the table. It was supported by the same spindle as the marking wheels; the two projections coming into contact with the under side of the wheel cylinder formed a means of securely fastening and supporting the die-holder. Short squaring blocks were fastened to the table against which the round work was located before marking.

Power for Compressors.*

Whether the cold storage or ice plant is large or small, the question of how the power for the compressor and the pumps is to be furnished is an important one. There are six possible sources of power that may be available. In some cases the proprietors of the plant have all the forms open to them, and it is a question of the most economical or the most convenient. Convenience, by the way, is often an important factor in the question of economy.

There is water power in those cases where it is available. The cases will be few in this country, but in the Colonies, in parts of Scotland, in Norway, in several parts of the continent of Europe, where coal is dear, water power, either applied directly or by the aid of electricity, is the most economical. Then there is steam power, which is available everywhere, if fuel of any kind and water can be obtained, and which has the advantage that the exhaust steam can be used for ice-making, after properly distilling, reboiling, etc., and can also be used for other purposes, where the heat remaining in the exhaust steam is of service.

Then there is the gas engine, which may be employed in connection with the town's gas, or by means of a producer worked on the premises; and the oil engine, which is very similar in many respects, the oil engine being really a gas engine, in which a gas is consumed that is made by converting the oil into vapor.

And, lastly, there is the electric motor, which again may take its current from the town or district service, or from a generating plant on the premises. The most economical method, it will readily be understood, will vary with the conditions, and there will be two broad divisions into which the plants may be divided—the large plant and the small plant. The conditions for producing power for any purpose are quite different when the plant is small from those which rule when the plant is large, for the reason that the interest on the cost of the plant, the attendance on it, and other charges bear very much more lightly on a large plant than on a small one, the amount being spread over so many more units. In the following article it is proposed to discuss the different forms of power applicable, with their costs under various conditions, so that users of cold storage and ice plants will have the whole facts at their command, and can easily decide which form is applicable to their case. Two or three cautions are perhaps necessary at the commencement. One is, to be sure that when estimating for the power required that you have all the quantities before you, all the charges that will be made. In a compression plant, for instance, there will be the power absorbed by the compressor, that taken by the circulating pump for the condenser, by the brine pumps, and by the fans, where these are employed. And, again, in estimating the power taken by all of these, the actual power must be ascertained, not what is usually called the theoretical power. In the early days of a new industry, trouble often arises over the power question, from the engineer taking what is erroneously called the theoretical power required, that which he makes out, by calculation at his desk, should be required. It is not the real theoretical power at all. It is the power calculated from formulæ which have omitted several terms of the equation. There have been many instances of professors and others complaining that the power they provided for a certain machine would not drive it, though according to their calculations it ought to have done so. A striking instance of this occurred at a meeting of the Mining Institute, where a professor pathetically complained that he had provided 20 horse-power in an electric motor to haul some mine wagons, but it would not move them, while one horse hauled them quite easily. The trouble was, the professor had not allowed for the power absorbed by the gearing and the machine on which the ropes worked, and had possibly over-estimated the power available at the motor. These cases are constantly occurring. It is not always easy to cor-

*By Sidney F. Walker, M.I.E.E.; M.I.Mech.E.; M. Inst. M. E., in *Ice and Cold Storage* (Eng.).

rectly estimate the actual power that will be required, as the requirements of certain portions of the apparatus, the gearing, for instance, are not always easily judged. Practical experience will always be the safe guide, and practical experience with an apparatus such as gearing, belts, ropes, etc., that is obtained in one form of work is usually a good guide in another. The safest guide, however, is an actual test, such as can easily be made now, where electrical power is available; and, failing that, a careful examination of the power that is doing the work under similar conditions. Thus, if it is intended to supersede, say, a steam engine by an electric motor, the safest guide as to the power required from the motor is the power taken from the steam engine it is to displace. Advantage may often be taken of the increased efficiency of one form of motor over another, that of the small electric motor, for instance, over that of the small steam engine, but the actual efficiencies of both should be ascertained, as will be explained, before arranging anything. A fairly good guide as to the power required can be obtained by taking the power absorbed in actually performing the work, say, in compressing the gas, and in any friction in the pipes traversed by the gas and liquid, which may readily be calculated, and then applying the efficiencies of the apparatus claimed by the makers. But again it is wise to allow a margin over and above what the calculation would show. It is also well to remember that the power required for a compressor, a pump, or a fan is the power delivered at its driving pulley, pump rod, or whatever may be used to deliver the power, while the power that has to be generated, or paid for if taken from a town service, includes the power absorbed by the motor itself; and again the proportion of the total power used, taken by the motor itself, varies with the work the motor is performing. If, for instance, the efficiency of the motor is ninety per cent., this means that ten per cent. of the power is absorbed in the motor. In many forms of motor the quantity of power represented by the ten per cent. remains as a charge, no matter what work the machine is doing. Thus, if an engine is built to furnish 100 indicated horse-power and its efficiency is ninety per cent., the 10 horse-power charged by the engine for converting the energy of the steam into mechanical power remains approximately constant, though the engine may be only developing 50 horse-power, or even 20 horse-power, and consequently the power usefully applied is a smaller proportion of that paid for. Makers of motors are sometimes very sanguine as to the capabilities of their apparatus, and all of these points must be taken into consideration in estimating the power required.

Proportioning Air Receivers.

It very often happens that shop foremen are called upon to determine what sized air receiver is best for their purpose, and probably very few such men are qualified to decide this point except by guessing or consulting a catalog. For the benefit of those who may not have a catalog at hand, the following may be of service:

1st. Determine the maximum capacity of the compressor per minute in free air. (Piston displacement per minute will do).

2d. Calculate what volume this air will occupy at the working pressure, and this will be the required volume of the receiver.

This is a very easy calculation to make, as the following example will illustrate:

Suppose the maximum piston displacement of compressor per minute = 65 cubic feet.

Working pressure = 80 pounds (gauge). To determine the volume of 65 cubic feet of free air when compressed to 80 pounds pressure, the following formula may be used:

$$V_2 = \frac{14.7 V_1}{P_2 + 14.7}$$

In which V_1 = Maximum piston displaceplacement in cubic feet per minute = 65.

P_2 = Working pressure (gauge) = 80 pounds.

V_2 = Volume of the air at the higher pressure.

Substituting in this formula we have:

$$V_2 = \frac{14.7 \times 65}{80 + 14.7}$$

= 10 cubic feet, which would be the volume of a receiver 18 inches in diameter and 6 feet long.

It is therefore possible, by using the above formula, to determine approximately

the minimum sized receiver necessary, but in making selection a larger one is preferable. There is no drawback in having the receiver too large; a receiver is seldom too large, in fact most troubles are caused by the receiver being too small to overcome fluctuations in pressure, and by not allowing the air to remain stationary long enough to cool and to deposit part of its moisture.

W. R. HULBERT, M. E.

Notes.

A pneumatic baseball is numbered amongst the newest inventions. It has a hollow core filled with air under pressure.

The Chicago Pneumatic Tool Co. announces that it has been awarded the gold medal at Liege covering pneumatic tools and appliances, and the silver medal for Franklin air compressors. The gold medal was the highest award for pneumatic tools and appliances.

The Westinghouse Electric & Manufacturing Company at Pittsburg, Pa., has followed its custom this year of issuing a pocket diary which contains not only a space for every day, but a great deal of useful information. Among the tables are those of special interest to mechanical and electrical engineers.

The Thompson-Curtis Company of Spencerport, N. Y., has been incorporated with a capital of $15,000. The company will manufacture devices for compressed air cleaning. The directors for the first year are L. B. Curtis, of Spencerport, E. D. Thompson, of Albany, and H. E. Ducker, of Buffalo.

It is now definitely decided that electric traction will be employed from the first in the Simplon Tunnel. The *Temps* announces that an agreement has been signed with a Swiss firm by which the necessary installation is to be completed by May 1, the date on which the tunnel is to be opened.

Mr. Ernest C. Howard, resident engineer of the Sixth St. Viaduct, Kansas City, Mo., recently issued unique invitations to what he called "An Informal Compressed Air Smoker." It was held 40 feet below the surface of the Kaw River, in the air chamber of the caisson for Pier No. 2.

The Ingersoll-Rand Company announces that it has secured exclusive control of the product of the Imperial Pneumatic Tool Company, with shops at Athens, Pa. The line of "Imperial" tools is well known and complete, including pneumatic hammers, drills, riveters, reamers, hoists and plug drills. The Ingersoll-Rand Company is the manufacturer also of the "Haeseler" pneumatic tools and the public is now offered the choice of these two distinct lines of tools of established merit.

According to press reports, compressed air has been used successfully in a Minnesota slaughter house for removing the hides from animals. A slit was made in the neck before the animal was killed and compressed air forced into the loose tissue between the skin and body. It is said that the skin was torn loose in a moment. A bullet then was fired into the animal's brain. In one instance, too high air pressure was used and the skin exploded, injuring two men and tearing the front out of the slaughter house. The authorities are reported to be likely to take action on account of the cruelty of this method.

An Italian engineer, Signor Jelpo, has invented a submarine elevator for raising wrecked vessels. The invention was recently put to a practical test, with complete success, in the Bay of Naples, where a stone-laden barge sunk a couple of years ago, and lying at a depth of about 50 feet, was brought to the surface with ease. The weight lifted was about 60 tons. The apparatus consists of compressed air chambers of canvas and wire, each equal to a lifting capacity of 60 tons, and it is possible to attach as many of these as may be necessary, after calculating the weight to be lifted. All the port authorities witnessed the experiment and warmly congratulated the engineer.—*Kansas City Journal.*

A thoroughly practical treatise, covering the subject of electric wiring, has just been published by the Norman W. Henley Publishing Company, of 132 Nas-

sau street, New York. This book is entitled "Electric Wiring, Diagrams and Switchboards," by Newton Harrison, E.E. The price is $1.50. It includes explanations and diagrams which are thoroughly explicit and greatly simplify the subject. Practical every-day problems are presented and the method of obtaining intelligent results clearly shown. Only arithmetic is used. Ohm's law is given a simple explanation with reference to wiring for direct and alternating currents. The fundamental principle of drop of potential in circuits is shown with its various applications. The simple circuit is developed with the position of mains, feeders and branches; their treatment as a part of a wiring plan, and their employment in house wiring clearly illustrated.

Following immediately upon Mr. Samuel Spencer's discussion in the January *Century* of "Railway Rates and Industrial Progress" from the point of view of the railroads, the February *Century* offers a discussion of the same subject from the point of view of those who favor the extension of government control over railway rates, by one intimately familiar with the President's attitude, Charles A. Prouty, member of the Interstate Commerce Commission. It is Mr. Prouty's contention that the only way to regulate the railway rate is by laying hold on the rate itself, and that some administrative body must be clothed with the power to determine and prescribe for the future—all parties recognizing existing conditions and joining with the President to provide a tribunal which can and will do justice between all parties. "If the Interstate Commerce Commission is not such a body," Mr. Prouty says, "let us have one that is."

The Milwaukee, Wisconsin, branch of the National Association of Cement Users has made extensive plans and arrangements for its exhibit at the convention of the National Association, and when the announcement was made that the National Association of Cement Users had decided to hold the convention at Columbus, Ohio, on account of the destruction by fire of the building originally selected for the exhibit of the association, the Milwaukee branch decided to hold an independent convention and gave due notice to the National Association to that effect.

This fact has again changed the plans of the National Association, and at a recent meeting of the executive committee, held in Philadelphia, it was decided to return to the original plan, viz.: that of holding the convention at Milwaukee, and on the dates originally specified, from the 9th to the 12th of January, inclusive.

The National Association has the assurance of the Milwaukee branch that adequate quarters have already been secured and all plans will stand as originally specified.

The School of Mines of the State University of Washington gives a course each winter for prospectors and mining men in general. It is the aim of the institution to make this course thoroughly practical. To that end, the instruction is principally by laboratory methods and visits to smelters and mines in operation. The course began January 9, and lasts three months.

Ores are tested in the new stamp mill and concentrating plant recently built at the University. The machinery for free milling ores consists of a Dodge breaker, grizzly, Challenge feeder, three-stamp mill, copper plates, mercury trap, Frue vanner, canvas table and Wilfley slimer. For concentrating copper and lead ores, the following are used: Breaker, roll feeder, Cornish rolls, revolving screen, three-compartment jig, hydraulic classifier, Pinder concentrator, Overstrom diagonal table, forges and a two-ton cupola furnace for foundry work. Students are given practice with all this machinery.

The expenses of the mining course are limited to the cost of textbooks, fees in the laboratory courses and deposits to cover materials used.

The explosive power of cordite may be utilized, says the *Westminster Gazette*, in other and more peaceful ways than that of providing the motive-power for shells. One of its latest uses is in starting heavy petrol engines from rest. A six-cylinder engine of 140 horse-power, which is being sent to America for driving the generator of an electric railway carriage, has three breech-blocks fitted to the first three cylinders. The firing of the first one starts the motor, the other two are fired at the proper time, and the last three cylinders

take their charge of petrol vapor in the ordinary way. When the engine is started the breech-blocks are thrown out of action and the usual ignition appliances put in gear. This method of starting is extremely simple and obviates the trouble usually experienced in moving such a heavy engine.

[We have observed the strong resemblance of the noise at a motor race, where mufflers are dispensed with, to a sham battle; but it seems that this class of engine is now developing into artillery using high-power explosives. A little compressed air seems to us better for the purpose, however.—Ed.]—*American Machinist.*

The management and equipment of the modern machine shop has grown to be an important problem which requires careful consideration and study. Except where compressed air is used for rock cutting, there are very few users of that form of power transmission who are not intimately interested in the questions regarding shop and factory organization and methods. We believe, therefore, that a book on the subject will be of special interest to many of our readers. "COMPRESSED AIR" has made arrangements to sell one of the newest and best written books on the subject, entitled, "Modern Machine Shop Construction, Equipment and Management." It is by Oscar E. Perrigo, M. E., an expert in machine shop and factory organization and modern shop methods. The book contains nearly 400 large quarto pages, illustrated by 200 engravings, especially made by the author.

It is a book written and illustrated by a practical shop man for practical shop men who are too busy to read theories and want facts. It will interest anyone from the apprentice in the shop to the president in the office. The first part deals with the construction of the factory, the second with the equipment of the plant and the third pertains to the management. This book will be forwarded, postage prepaid, on the receipt of $5.00.

Compressed air has recently been employed successfully as a substitute for a pump. It is conducted downward through a pipe, liberated in the reservoir or well from which the fluid is to be raised, and then enters another pipe which leads upward. In order to make the system work, the well must be inclosed in just the right way, so that no other channel of escape is left than the one which it takes. Air and water then alternate in the discharge pipe. Pressure serves as well as suction, apparently, and beyond a certain limit ought to work better.

A new application of the "air lift," as it is called, has just been made at Worcester, England. It has been employed to raise sewage from an immense reservoir, 20 feet in diameter, having a conical bottom into which the street dirt settles. It was originally intended to lift this sludge by a bucket elevator, but an "air lift" was finally installed. The discharge pipe is 6 inches in diameter and is inclosed by a larger pipe with a number of small quarter-bend pipes pointing downward attached to its lower part. Compressed air is discharged just below the entrance to the discharge pipe from a pipe carried down the side of the well. When the air is passed through the apparatus, the sewage in the well enters the space between the two pipes through slits in the upper part of the casing, passes down this confined space, to the bottom of the discharge pipe and then rises through the latter to the outlet.—*Tribune Farmer.*

American copper mines are famed for the magnitude and completeness of their mining plants. The Michigan copper country has long held first place in the competition for large and costly compressed air equipment. But a recent order placed with the Ingersoll-Rand Company, of New York, shows that the tendency toward centralization of air power in large units is working into other fields.

The management of the United Verde Copper Mine at Jerome, Arizona, has just contracted with the manufacturers mentioned above for a cross-compound condensing two-stage Corliss air compressor which, when installed, will be the largest compressor unit in Arizona and the southwest. The order calls for a 48-inch stroke machine, with steam cylinders 28 and 52 inches in diameter and air cylinders 44¼ and 26¼ inches. Steam cylinders are jacketed, with valves in the heads. The machine is to operate under 110 pounds steam pressure and a vacuum of 20 inches; a very high steam economy is guaranteed. The air cylinders will be jacketed on heads and barrels and will be

fitted with the "piston inlet" air valves. The compressor will run at 75 revolutions per minute, at which the piston displacement will be 6,060 cubic feet of free air per minute. The air pressure is to be 100 pounds and the altitude is about 5,500 feet.

The United Verde is popularly known as one of the greatest copper mines in the world, and the ordering of this large compressor seems to indicate that its immense ore reserves are still practically untouched.

A high-speed air compressor, of English make, was recently illustrated in *Machinery*, in which the principal feature of interest was the discharge valve, this being somewhat larger than the bore of the cylinder, forming, in effect, an inner movable head for the bore. Its object was to give not only a large discharge opening, but to reduce the clearance space to the minimum. The same result has been obtained in a high-speed ammonia compressor built by L. Stern & Co., Glasgow, much similar in construction but with somewhat different action. The construction differs, in that the inner cylinder heads for the double-acting piston are the discharge valve seatings, but they do not lift bodily from their seats, except when the piston runs over the limits of its stroke. The discharge valves are seated on the outer faces of the heads or seatings in the usual manner, and the seating is held in place by a heavy coil spring of sufficient strength to hold it firmly in place except when the piston over-runs. The piston is connected to the piston rods by two lugs attached to the sides and these lugs work in the suction chamber which surrounds the centre of the piston. The incoming ammonia gas passes from the suction chamber through large openings in the sides of the piston and from thence out through the small openings in the ends of the pistons, which are covered by light metallic plates, forming the suction valve. The clearance spaces are reduced to nearly zero and the length of the connecting-rod is adjusted so that normally the valve seatings at the ends of the stroke are not disturbed. The compressor may be run at high speed economically and without fear of damage, for in case the adjustment is lost the knocking will at once warn the engineer without causing a smash-up. An advantage of the design is that the piston rods are not subjected to great variations in temperature and the piston rod glands do not work against high pressure, thus reducing leakage and the friction losses of the machine.—*Machinery.*

Mr. Calvin W. Hendrick, chief engineer of the Baltimore Sewerage Commission, has announced a number of appointments to the leading positions on his staff. The first assistant engineer is Mr. Albert M. Broscius, recently an assistant under Mr. Hendrick on the work of the New York Rapid Transit Commission. He was assistant commissioner in charge of sewers in Baltimore during a previous administration and later was on the staff of Mr. Alexander Potter on the construction of the joint outfall sewer in northern New Jersey. The division engineer in charge of the disposal plant is Mr. Ezra B. Whitman, who was born in Baltimore, and served on the engineering staff of the United Railways & Electric Co. soon after his graduation from Cornell University. Afterward he made a study of sewage disposal in England and has since been engaged in the design of disposal works, of late as a partner in the firm of Williams & Whitman, of New York. The division engineer in charge of the low-level sewerage works is Mr. Kenneth Allen, well known to many readers of this journal through his previous connection with the Baltimore sewerage works as engineer of the commission of which Mr. Mendes Cohen was chairman. He has been chief engineer and superintendent of the Atlantic City water-works department for a number of years past, and several interesting pieces of work done there under his direction have been described in this journal during the last year or so. The division engineer in charge of the high-level sewers is Mr. Oliver W. Connet, at present assistant city engineer of Baltimore, in charge of sewers. The assistant engineer in charge of the central office is Mr. Herbert W. Knight. From 1896 to 1899 he was connected with the sewerage department of the city engineer's office in Providence, and since that time has been associated with the Continental Compressed Air Power Co. as local manager at Norwich, Conn. Mr. Frank T. Daniels, engineer of the drafting office, has long been connected with the designing department of

the Metropolitan Water and Sewerage Board, and is now principal assistant engineer under Mr. Stearns. These appointments take effect on the first of next year.—*Engineering Record.*

The English railway companies which have recently installed electricity as a motive power to take the place of the steam engine, were confronted with numerous difficulties in making the changes for the new system. For nearly thirty years the trains in the tunnels of the London District Railway have been drawn by the steam locomotive, and, in consequence, a vast accumulation of smoke and sulphur has collected on the domes of the tunnels. The presence of sulphur in combination with smoke has, in the course of years, made a thick coating of soot on the walls and ceiling of the tunnel. When it was attempted to remove the deposit in carrying out numerous improvements, it was found to be a task of great difficulty, because of the tenacious character of the deposit and also that only about three hours of the twenty-four were available for performing the work without interfering with traffic. This removal of the deposit was attempted by hand labor, but this method was soon abandoned as being too expensive and slow, and also an impractical way of doing the work. Numerous devices were tried, but every one of which resulted in failure, until the invention of Mr. Ward, the master mechanic of the Mill Hill sheds of the District Railway system, was brought into use. This invention is a most ingenious machine mounted on a fifty-foot motor truck and equipped with a compound brush—the manipulation of the various parts of the machine being operated by compressed air.

The brushes are mounted on a swivel and can be elevated or depressed at will and turned from side to side by the slightest touch of the hand. Connected with the brush are two double air compressors, working at a pressure of 200 pounds to the square inch. When the air is applied, the brushes revolve over the surface of the tunnel at a rate of 4,000 revolutions per minute.

Several trials have been made with the cleaner with most satisfactory results. The tunnels, after being thoroughly cleansed, will be whitewashed, considerably adding to the cheerfulness and comfort of the new mode of travel.

With the electrification of the numerous railroad tunnels in the United States, which has been rapidly progressing in recent years, it is apparent that the new tunnel sweeper could be used to advantage. The black walls of the ordinary railroad tunnel detract from a railway's equipment, from the passengers' point of view. A clean white tunnel is an advertising feature of every road so improved, and its value is self-evident.—*American Inventor.*

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz.: all communications should be written on one side of the paper only; they should be short and to the point.

We received the following communication from one of our subscribers.

"Inform me, if you have the information at hand, as to the quantity of natural gas at ordinary normal temperature and 100 pounds pressure that would flow through a 6-inch wrought iron pipe, *i. e.*, how many cubic feet per minute would it deliver at a distance of thirty-five miles."

The data given is incomplete as the allowable drop in pressure is also required. A practical drop will, therefore, be assumed and the problem solved accordingly.

A common formula for the flow of air, gas or steam in pipes is given in Kent's Engineers' Book.

$$Q = c\sqrt{\frac{(p_2 - p_1)\, d^5}{W\, L}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which

Q = cubic feet of compressed air, gas, or steam per minute.

c = experimental constant.

L = length of pipe in feet.

W = weight per cubic foot of compressed gas.

d = diameter of pipe in inches.

p_2 = initial pressure in pounds per square inch absolute.

p_1 = final pressure in pounds per square inch absolute.

It will be seen, therefore, that $(p_2 - p_1)$ is the difference in pressure causing the flow.

Equation (1) may be written

$$(p_2-p_1)=\frac{1}{c^2}\frac{Q^2\,W\,L}{d^5} \quad \ldots\ldots\ldots\ldots(2)$$

Now Q_0 equals the cubic feet of free air per minute and may be expressed by

$$Q_0=\frac{p_2}{p_0}Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where p_0 is the atmospheric pressure,

$$\text{Therefore } Q^2=\frac{Q_0^2 p_0^2}{p_2^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

We know

$$\frac{W}{D}=\frac{p_2}{p_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

in which

D = weight per cubic foot at atmospheric pressure p_0, and temperature T_0, at which Q_0 is measured.

$$W=D\frac{p_2}{p_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Substituting equations (3) and (5) in (2) we have

$$(p_2-p_1)=\frac{1}{c^2}\frac{Q_0^2 p_0^2}{p_2^2}D\frac{p_2}{p_0}\frac{L}{d^5} \quad \ldots\ldots(6)$$

$$(p_2-p_1)=\frac{1}{c^2}\frac{Q_0^2\,D\,L\,p_0}{d^5\,p_2} \quad \ldots\ldots\ldots(7)$$

Equation (7) is applicable only when the drop in pressure is small.

The drop necessary in the problem under discussion will be considerable and modifications of equation (7) must be made.

Let dp represent the drop in pressure over the distance dL, then form (7)

$$p\int_{p_1}^{p_2} dp=\frac{1}{c^2}\frac{Q_0^2\,D\,p_0}{d^5}\int_0^L dL \quad \ldots\ldots(8)$$

$$p_2^2-p_1^2=\frac{2}{c^2}\frac{Q_0^2\,D\,p_0\,L}{d^5} \quad \ldots\ldots\ldots\ldots(9)$$

The value $\frac{2}{c^2}$ has been found by experiment to vary according to

$$\frac{2}{c^2}=\frac{1+\frac{3.6}{d}}{3750} \quad \ldots\ldots\ldots\ldots\ldots\ldots(10)$$

and (9) takes the form

$$p_2^2-p_1^2=\frac{1+\frac{3.6}{d}}{250}\frac{Q_0^2\,D\,L}{d^5} \quad \ldots\ldots\ldots(11)$$

which is applicable to the flow of gas over considerable distances or where the pressure drop is great. This equation was developed by Mr. A. W. Hoffman, M.E.

Given:

$d=6$ inches.

$L=35$ miles $=184800$ feet.

$D=0.0435$ for natural gas at 60° F. for

$$D=\frac{32+461}{60+461}\times 0.046$$

$p_2=100$ # gauge $=114.7$ # sq. in. absolute.

Assume a drop of 2 pounds per mile, then the total drop is 35×2 or 70 pounds.

$p_1=114.7-70=44.7$ pounds square inch.

Substituting these values in equation (11)

$$(114.7)^2-(44.7)^2=\frac{1+\frac{3.6}{d}}{250}\times \frac{Q_0^2\,0.0435\times 184800}{7776}$$

$\therefore Q_0=1{,}299$ cubic feet of free air per minute.

That is to say 1,299 cubic feet of free air will be delivered at the end of a pipe line 35 miles long, but under a pressure of $p_1=44.7$ pounds absolute.

One of our readers writes as follows: "What power is required to drive a 1 inch diameter leather washer, similar to bicycle pump with power air compressor. The stroke is 5 inches, and pressure 100 pounds to the square inch. The stroke of this pump is adapted so that it will pump 100 pounds within two or three pounds, more or less, and maintain that pressure constant. When the pressure rises in excess of 100 pounds, the plunger simply compresses the air, but does not force it to tank. An average of 700 revolutions per minute is made, and the compressor is water-jacketed with cold water flowing around it at all times, also in the above advice, state what is the formula for figuring the power required."

The cubic displacement of a cylinder having 1 inch diameter and 5 inch stroke is 3.927 cubic inches or 0.0023 cubic feet. The energy necessary to operate the pump described with 100 pounds air pressure at 70 revolutions per minute will be identical with that needed to compress free air in the cylinder to 100 pounds pressure. This is not quite true as both compression and expansion are adiabatic and less energy is gotten out of the compressed air than is put into it, yet for the size pump you mention the difference will not cause any serious error.

To compress one cubic foot of free air in the single stage or compression to 100 pounds gauge pressure requires 0.207 horse power allowing 15 per cent. for friction. Assuming the pump to be single-acting, the free air capacity is 0.0023 x 700 or 1.61 cubic feet per minute.

The horse power necessary is, therefore, 1.61 x 0.207 or 0.333. If the pump be double-acting, then the horse power will be 0.333 x 2 or 0.666.

To the Editor of COMPRESSED AIR:

In your November issue appeared an article by Mr. Leicester Allen, which begins with the query "Why do not the builders of steam-driven blowing engines, instead of using air cylinders seven feet in diameter by five feet stroke, use cylinders of less diameter and, for a speed of only forty-two revolutions per minute, substitute a speed of one hundred revolutions per minute? The answer is, that "When builders of such engines know enough, they do."

In the *American Machinist* of November 23d, you will find a description of a blowing engine built by Mr. B. V. Nordberg, designed for a speed of 75 revolutions and which he offered to build for a speed of 86 revolutions. The writer not being willing to go to the extreme limit of present practice caused the reduction to 75 revolutions. Several other blowing engines built by Mr. Nordberg, along similar lines, are running 24 hours per day, 7 days per week, at 86 revolutions, without noise and without any trouble whatever from the air valves. The absolute silence of these engines would amaze anyone used to the noise of other blowing engines, even the most modern types.

As you may see fit to republish the description mentioned, I will not go into details here, but will say that I should have no hesitation in asking Mr. Nordberg to furnish a similar engine to run at 100 revolutions. The air cords from the engine mentioned are theoretically perfect and the amount of suction is hardly visible, even with a four-pound spring in the indicator.

Trusting that this answer to his question will be more satisfactory to Mr. Allen than his own, I am,

Yours truly,

J. E. JOHNSON, JR.

Longdale, Va.

FOR SALE.

At less than cost, the following imported Mannesmann tubes, designed for storage of compressed air:

12 tubes 20 ft. in length
78 tubes 15 ft. 4½ in. in length.

All designed for a working pressure of 2000 pounds per square inch and tested to 4800 pounds per square inch. All tubes are new and have never been in service.

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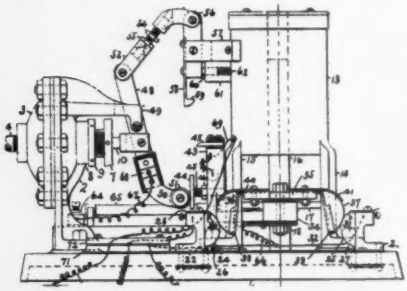
U.S. PATENTS GRANTED DEC., 1905.

Specially prepared for COMPRESSED AIR.

806,108. AUTOMATIC PRESSURE-REDUCING VALVE. Francis L. Clark, Pittsburg, Pa., assignor to The Westinghouse Air Brake Company, Pittsburg, Pa., a Corporation of Pennsylvania. Filed Jan. 15, 1903. Serial No. 139,159.

806,150. ELECTRIC AND PNEUMATIC GOVERNOR. Thomas F. Kelly, Philadelphia, Pa., assignor to John E. Reyburn, Philadelphia, Pa. Filed Nov. 11, 1904. Serial No. 232,300.

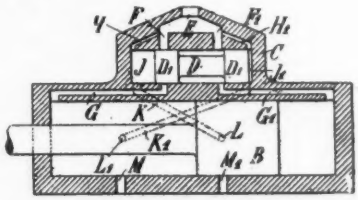


In a pneumatic and electric governor, a diaphragm and a solenoid, pneumatic connections to the diaphragm and electrical connections to the solenoid, a pole-plate for the solenoid, a bracket on the pole-plate which upwardly reaches and carries at one side an adjustable contact-plate, and at its top a latch-plate, a lever for the diaphragm having at its lower end a rotable contact-wheel and at its upper end a connection adjustable as to length which forms a connection to a centre fulcrumed lever carrying a spring-latch at its lower end so that upon an accumulation of pressure the contact-wheel will be moved to energize the solenoid, which will lift the pole-plate and cause the latch-plate to engage the latch adapted to engage the latch-plate aforesaid.

806,470. FLUID-PRESSURE REGULATOR. Arthur J. Hodge and Nathaniel Hodge, Pasadena, Cal. Filed May 9, 1904. Serial No. 206,984.

A pressure-regulator comprising a chamber provided with gas inlet and outlet means, a diaphragm exposed to the pressure in said chamber, means for adjusting the pressure on said diaphragm, a valve controlling the gas-inlet means, an operating connection between the diaphragm and the valve, and adjusting means connected to the operating connection to adjust the valve toward and from its seat.

806,128. ROCK-BORING MACHINE. Heinrich Flottmann, Bochum, Germany. Filed Oct. 15, 1903. Serial No. 177,192.



In valve-gears for engines driven by compressed air and like driving mediums in combination with a cylinder and a single working piston therein a valve-casing, a valve-piston located therein and having enlarged heads at both ends and a reduced middle portion, an admission-port, channels H, H′ leading from said admission-port to spaces at both sides of the said valve-piston, other channels K, K′ leading at opposite sides into the working-cylinder space and exhaust-openings M, M′ corresponding in position with the openings L, L′ of the channels K, K′ into the working cylinder.

806,462. AUTOMATIC CONTROLLER FOR ELECTRICALLY-ACTUATED COMPRESSORS. Niels A. Christensen, Milwaukee, Wis. Filed May 13, 1898. Serial No. 680,536.

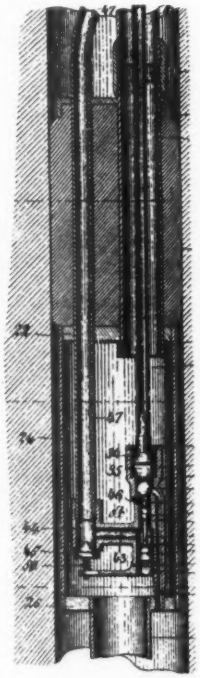
In a controller for electrically-actuated compressors, the combination of a switch to be located in the circuit of the electric motor, a fluid-motor for operating said switch, a valve for controlling the admission and release of the actuating fluid to and from said fluid-motor, comprising a valve-seat which has a central supply port or passage, two service-ports and two exhaust-ports, and a valve-disk which has an axial supply-passage in full and constant communication with the supply-passage in said seat, two through-ports arranged to register alternately with the service-ports in said seat, and two cavities arranged to connect the associated service and exhaust ports in said seat alternately, and a fluid-motor for operating said valve having a fluid-supply connection for the compressor, substantially as and for the purposes set forth.

806,511. EXCAVATOR. William H. Arnold, Brooklyn, N. Y. Filed Mar. 9, 1904. Serial No. 197,341.

The combination in a dredging apparatus of a frame pivoted on a horizontal axis, a pedestal supporting the same and capable of being turned

on a vertical axis, a movable carriage or platform supporting said pedestal, a slide guided in the pivoted frame, dredging-buckets and fluid-pressure devices for actuating the same mounted on the slide, and fluid-pressure devices also mounted on the frame and directly connected with said slide as and for the purpose described.

806,557. LIFTING APPARATUS FOR DEEP WELLS. Fred J. Moser, Kane, Pa. Filed Nov. 7, 1904. Serial No. 231,689.



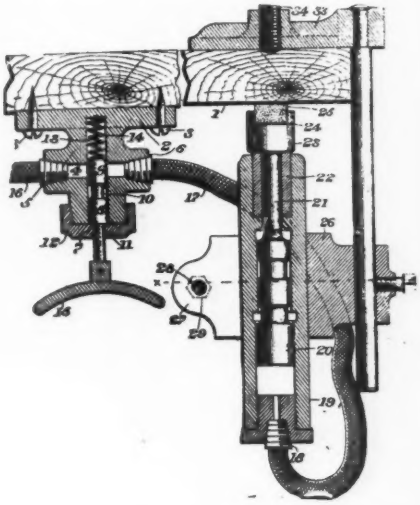
In an apparatus of the character described, the combination of means controllable by air-pressure for intermittently forming the liquid within the well into successive columns of great height, valve mechanism controllable automatically by fluid-pressure for successively forcing charges of air into said successive columns of said liquid, and vent mechanism to prevent said valve mechanism from fouling.

807,037. FLUID-PRESSURE BRAKE. William P. A. Macfarlane, Chicago, Ill., assignor to Richard Fitzgerald, Chicago, Ill. Filed July 18, 1905. Serial No. 270,216.

806,609. AUTOMATIC GOVERNOR FOR PNEUMATIC MOTORS. Joseph Wieser, New York, N. Y. Filed Mar. 2, 1905. Serial No. 248,128.

In a governor for pneumatic motors, in combination, with the motor-bellows, and the passage for suction air communicating with the fixed part of the same, an interior valve in said motor-bellows slidable upon the fixed part of the same and provided with an opening adapted to be shifted into or out of register with said passage, and means for actuating said valve.

806,740. PNEUMATIC RAPPER. Harry B. Griner, Philadelphia, Pa., assignor to Chicago Pneumatic Tool Company, Chicago, Ill., a Corporation of New Jersey. Filed Dec. 14, 1904. Serial No. 236,811.

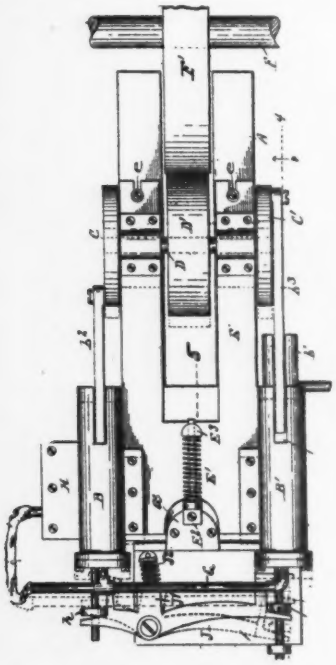


In a pneumatic bench-rapper, the combination of a pneumatic tool, a rapping device actuated thereby and constructed to be reciprocated to vibrate the mold-support by impact, means for leading motive fluid to said tool, adjustable holding means for said tool and rapping device and embodying a lower clamping-jaw in which said tool is held, and a controlling device wholly independent of said tool and adapted to be actuated by the knee or body of the operator.

807,128. SHARPENING-MACHINE FOR DRILL-BITS. Theodore H. Proske, Denver, Colo. Filed Jan. 24, 1905. Serial No. 242,517.

807,287. SIGNALING AND TRAIN-CONTROLLING SYSTEM FOR RAILWAYS. Frank E. Kinsman, Plainfield, N. J. Filed Apr. 18, 1905. Serial No. 256,289.

806,924. AIR-COMPRESSOR. William J. Schultz, Detroit, Mich., assignor of one-half to Charles L. Vieman and William H. Turner, Detroit, Mich. Filed June 11, 1904. Serial No. 212,076.



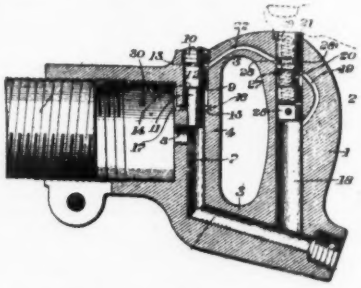
SCALE - ½" = 1 FOOT.

In an apparatus of the class described, a reciprocating carriage, compression-pumps mounted thereon, a frictional driving-pulley mounted on said carriage and geared to operate the pumps, a main driving-pulley to operate said pump-pulley, means operated by the air under compression to shift the pump-driving pulley into or out of frictional driving contact with the main driving-pulley as determined by the air-pressure itself, substantially as described.

807,288. PNEUMATIC MOTOR. Eugene de Kleist, North Tonawanda, N. Y. Filed Dec. 21, 1903. Serial No. 185,965.

In a pneumatic motor, the combination with a shaft having a plurality of cranks, of a series of pneumatics connected with said cranks, a wind-board having air-channels leading to the responsive pneumatics, each of said channels being provided in one of its walls with a suction-port and an air-inlet port arranged in line with each other lengthwise of the channel, sliding suction and inlet valves applied to the corresponding ports of each of said air-channels, a connection between the suction and air-inlet valves of each pair, and means for connecting each pair of valves with the companion crank on said shaft, substantially as set forth.

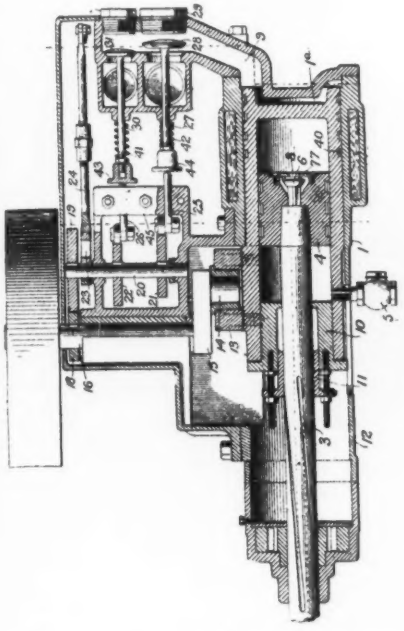
807,384. HANDLE FOR PNEUMATIC TOOLS. William H. Keller, Philadelphia, Pa., assignor to Chicago Pneumatic Tool Company, Chicago, Ill., a Corporation of New Jersey. Filed Mar. 29, 1904. Serial No. 200,645.



The combination of a pneumatic-tool handle, a throttle-valve outside of the grasping portion of the handle for controlling the admission of motive fluid to a pneumatic tool and means also outside of the grasping portion of the handle for operating said valve in both directions by fluid-pressure.

807,386. SIGNALING AND TRAIN-CONTROLLING SYSTEM FOR RAILWAYS. Frank E. Kinsman, Plainfield, N. J. Original application filed Apr. 18, 1905. Serial No. 256,289. Divided and this application filed July 24, 1905. Serial No. 270,931.

807,399. GAS ROCK-DRILL. John V. Rice, Jr., Edgewater Park, N. J. Filed Oct. 8, 1900. Serial No. 32,360.

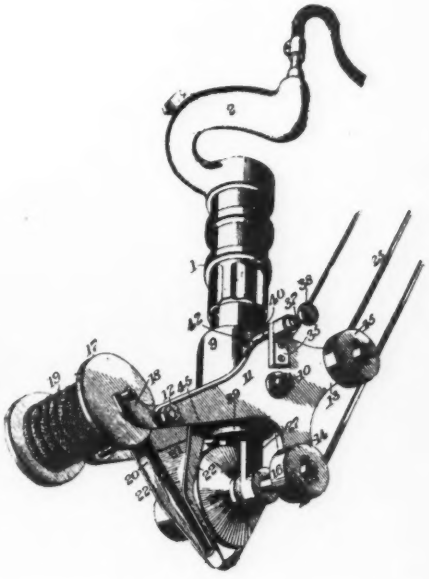


The combination of the main cylinder having at one end an explosion-chamber, a hollow, elongated piston, a piston-rod elastically connected to said piston, a cross-head on the piston, a crank-shaft actuating said cross-head, a cam-shaft parallel to the crank-shaft and driven thereby, and the inlet and outlet valves controlled by the cams of said shaft.

807,456. CAISSON. Edward N. Gilbert, Canadian, Tex. Filed Apr. 21, 1905. Serial No. 256,751.

A caisson embodying an earth-trap, means for supplying liquid under pressure to the lower portion thereof, and pneumatic earth-discharging means arranged in the upper portion of the trap.

807,407. CALKING PROCESS. Joseph J. Tynan and Harry C. Mostiller, Philadelphia, Pa., assignor by mesne assignments, to Chicago Pneumatic Tool Company, Chicago, Ill., a Corporation of New Jersey. Filed Feb. 5, 1904. Serial No. 192,200.



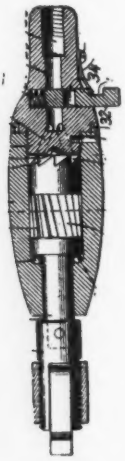
The method of calking which consists in supplying the material under tension, and calking the seam by a blow upon a rotary tool delivered in such a direction that the tool is advanced and a further supply of material drawn down into the seam as the result of the blow.

807,537. PNEUMATIC TIRE. Edgar M. Birdsall, Buffalo, N. Y., assignor of one-half to Mary B. Birdsall and one-half to Fletcher J. Barron, Buffalo, N. Y. Filed Jan. 26, 1904. Renewed May 22, 1905. Serial No. 261,665.

807,452. HAND PNEUMATIC TOOL. Emil Franke, Hicksville, N. Y. Filed Sept. 2, 1905. Serial No. 276,871.

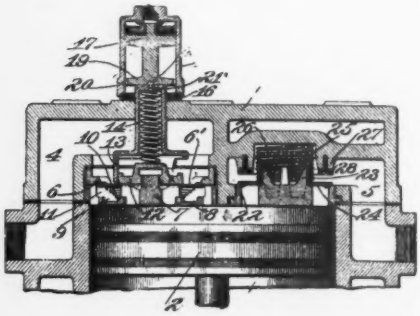
A hand-tool comprising a casing, a rotary member therein having a set of turbine-blades on one end thereof and a second set of turbine-blades intermediate the ends thereof, said second set of turbine-blades being adapted to be impinged upon by motive fluid directed tangentially against the periphery of the rotary mem-

ber, means for securing an implement to said rotary member, and means for directing motive



fluid slantingly against the first set of turbine-blades and tangentially against the second set of turbine-blades.

807,585. VALVE FOR AIR-COMPRESSORS. Edwin H. Steedman, St. Louis, Mo. Filed Nov. 2, 1903. Serial No. 179,596.



In a suction-valve mechanism for air-compressors, the combination with a flat annular valve formed from thin sheet material, of a valve-casing consisting of two parts, one having a seat for the valve, and being of skeleton form, and the other having a plurality of guides for supporting the valve at its inner and outer marginal edges in its open position, and a valve-holding spring interposed between the valve and the supporting part; substantially as described.

807,709. PNEUMATIC SAND-SHAKER. Albert H. Barber, Watertown, N. Y., assignor to Elmer Elsworth Hanna, Chicago, Ill. Filed Dec. 4, 1902. Serial No. 133,864.

In a pneumatic sand-shaker, the combination of a spring-mounted riddle-holder for moving the parts in one direction, and a fluid-pressure cylinder provided with a reciprocating piston projecting out of one end thereof separate from and resting against the screen-holder to operate the parts in the other direction, substantially as described.

807,876. PNEUMATIC CHUCK. Hugo R. Slivinski, Chicago, Ill., assignor to International Harvester Company, a Corporation of New Jersey. Filed June 19, 1905. Serial No. 265,891.

In a pneumatic chuck, in combination, a cylinder, a piston and piston-rod in operative relation therewith, a chuck-head secured to the free end of said piston-rod, hub-gripping arms pivotally mounted on said chuck-head, and means longitudinally fixed secured to the end of said cylinder for actuating the said hub-gripping arms.

808,022. AUTOMATIC CUT-OUT FOR ELECTROPNEUMATIC BRAKES. Edward H. Dewson, Edgewood Park, Pa., assignor to The Westinghouse Air Brake Co., Pittsburg, Pa. Filed Apr. 19, 1905. Serial No. 256,469.

808,174. ROTARY FAN. Howard D. Slear and Chester G. Arnold, Grangeville, Idaho. Filed Apr. 19, 1905. Serial No. 256,452.

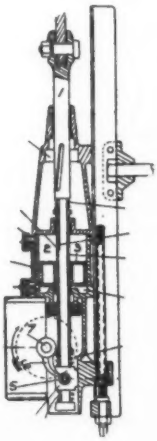
808,194. DOUBLE-ACTING SPRAYER. Frank S. Carothers, Jersey Shore, Pa. Filed Mar. 22, 1905. Serial No. 251,487.

808,238. EMERGENCY BRAKE-VALVE. George H. Hill, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed June 24, 1904. Serial No. 213,943.

808,271. EMERGENCY CONTROL SYSTEM. Frank E. Case, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed June 24, 1904. Serial No. 213,931.

808,314. CAR-BRAKE. Charles H. Shaner, McKeesport, Pa. Filed Mar. 31, 1905. Serial No. 253,078.

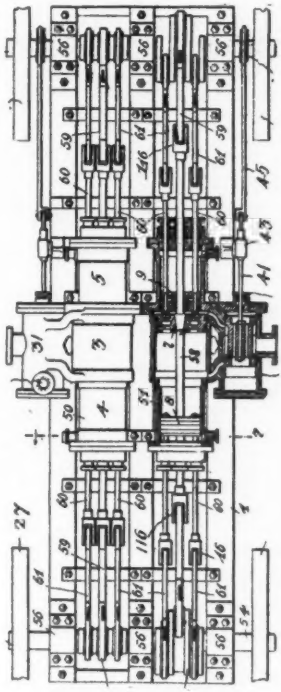
808,377. ROCK-DRILL OF THE PERCUSSION TYPE. Walter C. Johnson and George C. Pearson, Old Charlton, England. Filed Aug. 26, 1904. Serial No. 222,212.



In a drill, a cylinder, a piston therein, a working tool associated with said piston, means for moving the piston to the rear end of the cylinder to compress a charge of air therein and releasing the same to permit it to move forward under the expansion of the air compressed on the rearward stroke, and means for causing the air in the cylinder in advance of the piston during the forward movement thereof to successively pass into the atmosphere, to pass to the cylinder in rear of the piston, and to form a cushion for said piston.

808,411. LIQUID-AERATING DEVICE. William M. Venable, Cincinnati, Ohio, assignor to Sanitary Engineering Company, a Corporation of New York. Filed Nov. 15, 1904. Serial No. 232,815.

808,526. COMBINED STEAM-ENGINE AND AIR-COMPRESSOR. Charles Fero, Sr., Bay City, Mich., assignor of one-half to Jacob P. Benden, West Bay City, Mich. Filed Nov. 3, 1904. Serial No. 231,272.



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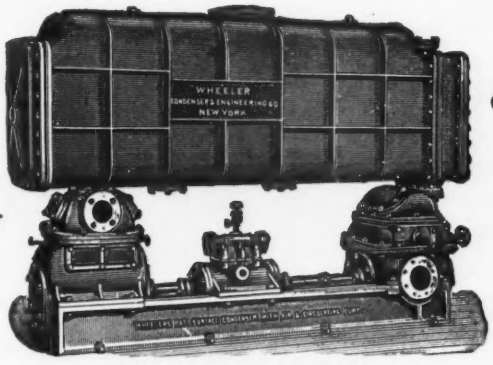

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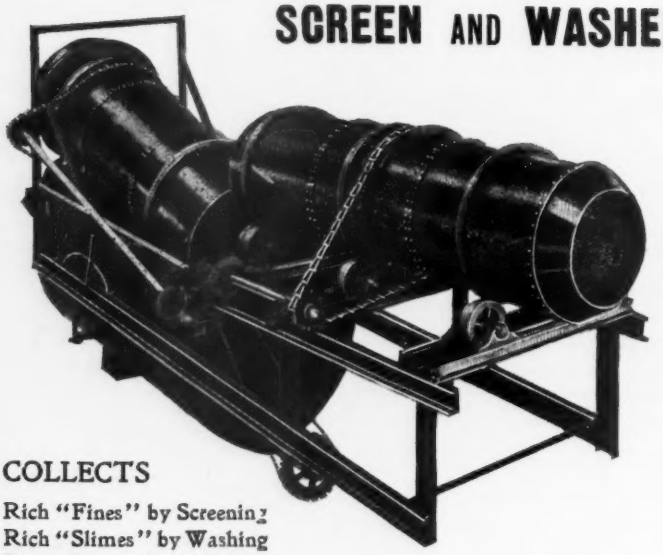

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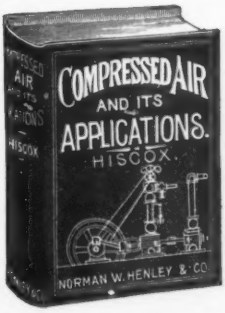

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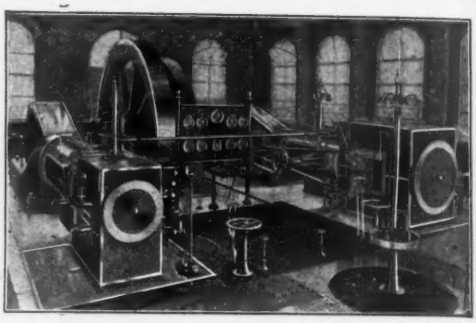

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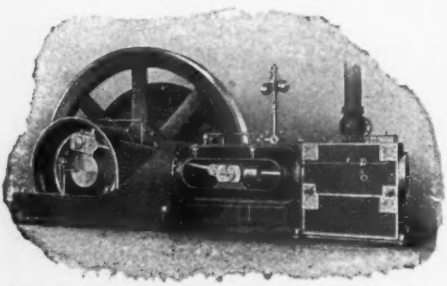

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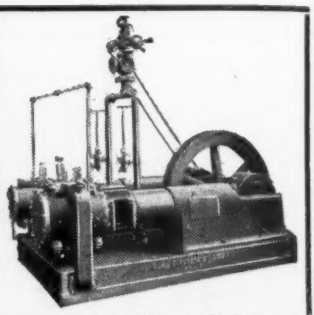

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